INTRODUCTION · TO SCIENCE ·

CALDWELL AND CURTIS

HOPPIN

INTRODUCTION TO SCIENCE

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PREFACE

The course in general science is designed to be a purposeful part of the life and thought of the pupils who study it. Those interests in science which are helpful and enjoyable are used, encouraged, and developed. The spirit of inquiry regarding the facts of life and experiences is used as a means of developing a working belief in guidance by truth. General science tries to give to pupils not only scientific attitudes toward common occurrences but the beginnings of acquaintance with the leading divisions of science knowledge.

The content presented in this book was determined by a synthesis of the important published results of investigations. Eighteen earlier investigations constitute the basis of this synthesis. Some of these eighteen were themselves comprehensive presentations of other studies. This synthesis[1] provides a kind of determination that has not previously existed as to what units and topics within the units should compose the general science course. The topics included and the units under which they are organized, while in essential harmony with those presented in the previous general science texts in which the senior author has coöperated, are now given an added validity as a result of the synthesis. The methods of presentation and the devices for instruction are also based upon recent investigations which deal with introductory science. The new book offers a somewhat simpler and more elementary course than Caldwell and Eikenberry's "Elements of General Science."

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[1] Francis D. Curtis, A Synthesis and Evaluation of Subject-Matter Topics in General Science. Ginn and Company, 1929.

The general tendency at the present time is toward a full year of general science followed by a full year of general biology. In some school systems general science is taught as a part-time subject through two junior-high-school years, or it may be a full-time subject in either the eighth or ninth years. Therefore this general science text includes the content found most desirable for a full-time year's course of instruction.

The materials of the course are organized in three groups. Those paragraphs designated with a star discuss the minimum essential topics which, according to the synthesis referred to, have the highest value; that is, a value of 53 per cent or more, as shown in the investigation. Those indicated with the dagger have a value of from 47.5 per cent to 53 per cent. The paragraphs with the dagger do not discuss any topics with a value of less than 50 per cent unless those topics were found in at least two different groups of sources. The remaining paragraphs constitute about 35 per cent of the total content of the book. The book therefore consists of about 35 per cent starred paragraphs, nearly 30 per cent daggered paragraphs, and about 35 per cent unmarked. It is expected that all pupils will master the essential content of the starred paragraphs; that the average pupil will also master many of the daggered paragraphs; and that the superior pupil will master also much of the unmarked paragraphs. This plan of organization is designed to facilitate individual assignments according to individual abilities and interests, and makes it possible to follow the lesson plan, the contract plan, or any other plan of individualized instruction.

To further facilitate individual work, three other types of materials are provided: (1) special reports, which are intended to range in difficulty from very simple ones within the capabilities of all the pupils to those that will challenge the best efforts and abilities of the most capable pupils; (2) problems, which include all the types of questions and problem situations which have been found by specific investigations to be appropriate to science teaching; (3) projects, used here by the authors in the sense that a project is an activity which the pupil must carry out independently and which requires construction work of some nature, and not merely a topic, or a problem, or an assignment to library work. While the book includes more materials than are expected to be mastered by any one pupil, these materials are organized with specific groupings which provide for those types of individual instruction which are now regarded as essential in effective teaching.

The vocabulary is confined almost entirely to the 5000 most frequently used words in the English language as determined by the investigations of Thorndike.[1] Use has also been made of vocabulary studies by Powers.[2] New words which are necessary are defined in simple terms and their pronunciations indicated at the bottoms of the pages where they first appear. Furthermore, new words are used frequently in succeeding discussions in order to develop familiarity with them. This plan insures the pupil's acquiring the accepted and appropriate terminology which he must have if he is to deal effectively with the new ideas. Definitions are not given for new words which are names of chemicals, of organizations or bureaus, directions of the compass, and of places or dates, or colloquial expressions, since such new words are adequately clarified by the forms of expression in which they appear. A glossary includes the scientific terms together with reference to the page on which each first appears and on which it is defined. This plan for definite procedure in vocabulary building is an important feature.

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[1] E. L. Thorndike, The Teacher's Word Book. Bureau of Publications, Columbia University, 1921.

[2] Samuel R. Powers, "A Vocabulary of Scientific Terms for High School Students," *Teachers College Record*, Vol. 28 (1926).

At the beginning of each chapter a short list of significant questions is presented. These questions are designed not as material for examination but as study guides to acquaint the pupil with the ideas with which the chapter is to deal. He will find scattered through the chapters, at points where they are likely to be most effective, pertinent, and stimulating, an abundance of other questions and problems of a wide variety of types.[1]

At the ends of chapters new-type tests of various kinds are presented. These test items apply only to materials in the starred paragraphs. They may therefore be used either as guides for directed study or as a test upon minimal essentials. These tests are examples which may be used both by teachers and pupils in building additional test items to serve as tests or as specific exercises in review. Summaries are provided at points within the chapters where they are desirable.

The book is in no sense a revision of any previously written book. The illustrations are new and many are *action drawings* showing pupils performing experiments or demonstrations. This type of illustration, the action drawing, will be found a most important addition to the more common types of illustrations. The illustrations, with their accompanying questions and comments, are an essential part of the teaching equipment of the book. The materials included in the book have been used through several years in junior-high-school classes.

THE AUTHORS

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[1] Harry A. Cunningham, "Types of Thought Questions in General Science Textbooks and Laboratory Manuals," *General Science Quarterly*, Vol. 9 (1925).

ACKNOWLEDGMENTS

In the case of any book the materials of which have been collected and tested bit by bit with pupils over a long period of years, it is impossible to mention individually all whose help and criticism have influenced the final presentation of subject-matter materials. The authors of this book wish to make grateful acknowledgment to the large number of teachers and graduate students who through their helpful coöperation have made contributions to the materials from which this book has been made. They wish also to acknowledge with special thanks the help of subject-matter specialists and teachers who contributed to the improvement of the final manuscript: to Professors Gerald W. Fox, W. C. Rufus, Henry H. Higbie, and Irving D. Scott, of the University of Michigan, for critical reading of the portions of the manuscript pertaining to their special fields of science; to Professor Marshall L. Byrn, of the University of Michigan, for assistance in development of projects and other materials; to Professor Roy K. McAlpine, of the University of Michigan, for valuable criticism of certain topics dealing with chemistry; and to Mr. Gerald G. Woods, of the University of Michigan High School, and Mr. Floyd I. Leib, of the Lincoln School of Ypsilanti, for valuable coöperation in teaching units of the book in manuscript and for criticism of other units.

The authors wish also to acknowledge their obligation to Professor W. L. Eikenberry of the East Stroudsburg, Pennsylvania, State Normal Teachers College, whose pioneer work in the field of general science has contributed much to the establishment of the subject in its present position in the high-school science curriculum, and whose practical and effective pedagogy has influenced the presentation of materials in this book, as indeed in all textbooks of general science.

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INTRODUCTION TO SCIENCE

UNIT I. INTRODUCTION

CHAPTER I

HOW KNOWLEDGE GROWS

Some Questions this Chapter Answers

Where are scientific problems found? How do we find the answers to scientific problems and questions? What is an experiment? Can people who are not trained scientists perform experiments? Do things happen without a cause? How may one become a scientist? What is meant by "the scientific attitudes"?

1. They wanted to know. During one of their "hikes" not long ago two boy scouts stopped to cook their camp supper. One got out his knife to cut some kindling for the fire.

"Look, Jim, the little blade of my knife is all rusty, but the big one isn't, at all."

He held up his knife to show the rust. Jim glanced at the knife without much interest.

Bob continued to stare at his knife. After a moment he said, "I wonder what made the little blade rust while the big one did not."

"Who cares?" said Jim. "Come on; let's hurry and get the fire started. I'm about starved."

"But I'd like to know how it happened," Bob protested, starting once more to cut kindlings for their fire.

"Oh, well, it just happened that way. Strange things do just happen sometimes, you know."

"You know better than that, Jim. You know that nothing ever happens unless something makes it happen. Maybe the little blade rusted just because it is smaller than the big one."

"That's silly. If that were so, big steam engines wouldn't rust, and small iron things, like nails, would. And you know the engine in the old mill is rusted to pieces. Maybe the little blade isn't made of the same stuff as the big one."

"It is, though. Both of them say 'Eureka Steel' on them. Maybe something happened to the big one to keep it from rusting that didn't happen to the little one, or the other way round." Bob lighted the shavings and arranged the larger pieces of wood on top.

Jim picked up the knife and looked at it thoughtfully. "I've got it! Remember when we were over at the Big Woods last Wednesday you dropped your knife in the water. We were in a hurry, and you just shook the water from the knife without drying it. That's why it rusted."

"Yes; I guess that's why it rusted, all right; water does rust steel." Bob scratched his head thoughtfully. "But that doesn't tell us why the little blade rusted and the big one didn't. They were both wet."

Both boys now examined the knife with care (Fig. 1).

"Look, Jim, see this grease at the handle-end of the big blade? Remember just before I dropped the knife into the water I was slicing bacon to fry? I used the big blade. So there was grease on the big blade and not on the little one. That's why the big blade didn't rust."

"That *sounds* all right. I know oil keeps things from rusting, but I don't know whether bacon fat does. Let's try it again and see. Today I'll cut the bacon with the *little* blade of *my* knife and not the big one. Then I'll drop it into the water just as you did, and then shake it off without drying it, just as you did, and we'll see what happens. It's an old knife; I don't care what happens to it, but both blades are bright now."

FIG. 1. BOTH BOYS NOW EXAMINED THE KNIFE WITH CARE

The boys did as Jim suggested, and a week later found that the big blade had rusted, while the little one had not.

What did the boys prove by their experiment? Why did Jim suggest trying the experiment with his knife? Why did he suggest cutting the bacon with the little blade and not with the big one? Why did he suggest dropping the knife into the water again and shaking it off just as Bob had done?

2. A good way of finding out. The boys used good scientific[1] methods. They considered several possible solutions of their problem with the rusty little blade before they finally thought of what seemed to them the correct solution; then, to make sure that they had the correct one, Jim planned a clever experiment of his own to test it. By this experiment the boys added some interesting and valuable facts to what they already knew. They would be able later to tell these newly discovered facts at home, in Scout meeting, or in their science class.

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[1] *Scientific* (si en tif′ik): careful and exact in learning the facts; using the methods of science. We need to learn new words to help in our thinking as our knowledge grows. Useful new words are explained at the bottom of the page upon which each first appears. For your convenience new words are listed in the back of this book.

Knowledge grows in this way. People bring together all the facts which they learn by observing [1] and experimenting.[2] Then the scientists [3] put all the related facts together in an orderly arrangement, making this growing knowledge more easy to use.

3. You can become a scientist. You do not need a laboratory [4] full of strange and expensive apparatus,[5] though most of the great scientists do work in such laboratories. You can train yourself to be a scientist by always looking for questions and problems in your environment [6] (Fig. 2) and by then trying to solve the problems in the same way that the boys solved theirs — by careful observing and experimenting.

Not every boy and girl can expect to become a great scientist whose discoveries add to the beauty and comfort of the whole world, as many scientific discoveries do. Every boy and girl can add greatly to his or her own pleasure and information by cultivating habits of scientific observing and experimenting, and some may really become great scientists.

---

[1] *Observing* means more than looking: it means looking and thinking about what one sees.

[2] *Experimenting* means trying things out in order to learn from them.

[3] *Scientist* (si′en tist): one who makes a study of science; that is, of things found in nature.

[4] *Laboratory* (lab′o ra to ry): a place where a scientist works.

[5] *Apparatus* (ap a ra′tus): the bottles, dishes, scales, machines, and similar things which a scientist uses in his experimenting.

[6] *Environment* (en vi′ron ment): All the surroundings and conditions among which we live make up our *environment*. Air, water, food, light, heat, sound, soil, animals, plants, and people are some of the chief factors of our environment. Some other factors (that is, things which influence us) in our environment are houses, automobiles, and electric lights.

As you walk to and from school, or wherever you go, you can discover in your environment hundreds of problems and questions. Cultivate the habit of looking for them with your eyes, your ears, and your nose, for a scientist observes by means of all his senses. Some of these problems you will already be able to answer; some you will be able to solve by further observation, clear,

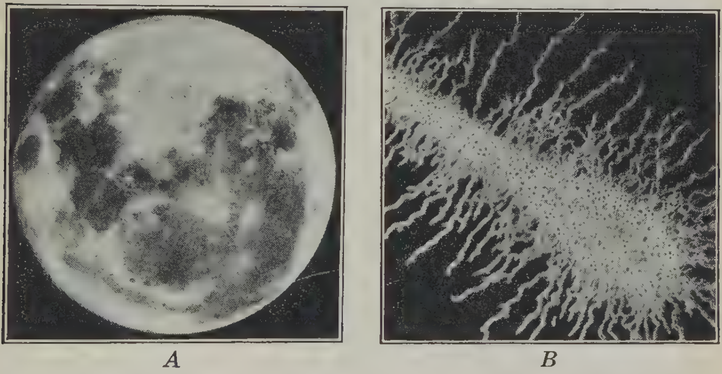

FIG. 2. EXTENDING AND EXPLORING OUR ENVIRONMENT

A: The moon, as it looks through a telescope (photograph by the Yerkes Observatory). *B:* Molds and bacteria which grew in a fly's footprint, as they look through a microscope ("Secrets of Nature," Educational Department, British Instructional Films, Ltd.). We can explore and extend our environment by using scientific inventions like the telescope and the microscope. How can we also extend our environment by using the automobile and the radio? How many other scientific inventions can you name which help us to explore and extend our environment?

careful thinking, and careful experimenting; some you will be unable to solve; and some perhaps nobody will be able to solve for many years to come, if ever (Fig. 3).

> Here are some scientific problems which you may have found on your way to school. What bird is that? Why do the leaves change color and fall from the trees? Was it a bird or a squirrel that made that sound? What made the hollow in the pavement? How can the men get the steel up to the top of that new building? What makes the railroad engine puff?
>
> How many scientific problems like these can you see from the schoolroom window? Can you think of others which you saw on your way to school?

You may ask "Are scientists different in their work from most people in the way they think and act? What should I know about the ways in which scientists think and act so that my knowledge may grow in the same way?"

4. How a scientist thinks and acts. Anyone can cultivate the scientific attitudes. No one can become a real scientist unless he has trained himself to think and act according to these attitudes. They are very important. You will be given many opportunities in this course to show how well you know them and can apply them.

The following is a list of the chief scientific attitudes:

a. A scientist believes that nothing can happen without a cause.

b. A scientist does not believe in superstitions,[1] such as charms or "signs" of good or bad "luck."

c. A scientist believes that strange and mysterious things are capable of being explained finally by natural causes.

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[1] *Superstition* (su per stish′un): a belief in causes which are not natural. Superstition always has fear in it. *Superstitious* (su per stish′us): believing in superstition.

d. A scientist is slow to accept as facts such statements as are not supported by convincing proof.

e. A scientist does not believe that there is necessarily any connection between two events just because they happen at the same time.

f. A scientist is curious about everything in his environment.

g. A scientist tries always to be careful and accurate[1] in his observations.

h. A scientist prefers, whenever possible, to do his own observing and experimenting. He does not hesitate to use, whenever it will help him, the results of other people's observations, provided he knows that these other people are scientists whose statements can be depended upon.

i. A scientist patiently collects his facts by making his observations over as long a period of time as is necessary in solving his problem.

FIG. 3. OBSERVING, THINKING, AND EXPERIMENTING

"Something has been eating my plants. It must have been a bug or worm. I must find a toad to put with my plants. If he doesn't eat the bugs and worms, I will spray the plants." How is this girl illustrating observing, thinking, and experimenting?

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[1] *Accurate* (ak′u rate): exact and true. *Accuracy* (ak′u ra cy): the quality of being accurate.

j. A scientist continues to hunt for satisfactory explanations of the phenomena[1] he observes until he is convinced that he has found as nearly a correct explanation as the evidence permits. He is willing to change his conclusion if later evidence shows that his first conclusion was wrong.

k. A scientist does not express his opinions or announce his conclusions until he has considered the matter from all sides.

l. A scientist does not begin to experiment blindly and carelessly. He carefully plans to do his work in what seems, after careful thought, to be the best way.

m. A scientist considers for himself all the evidence he hears and the facts he learns, and tries to decide whether they really have to do with the matter which is being considered, whether they are sound and sensible, and whether they are complete enough to allow him to draw a conclusion from them.

n. A scientist respects another's point of view. He is open-minded and willing to be convinced by evidence. In other words, he would say: "I may very easily be wrong in my beliefs or opinions or conclusions. I will not change these without convincing evidence, but I shall always be willing to change them if somebody shows me proof that I am wrong."

5. **Science depends upon accurate measuring.** Much of the progress which the scientists have made in controlling and improving the environment has become possible because they have been learning more and more new facts about the various kinds of matter in the world about us. The wonderful feats of modern engineering

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[1] *Phenomenon* (fe nom′e non); plural, *phenomena* (fe nom′e na): *Any* happening is a phenomenon.

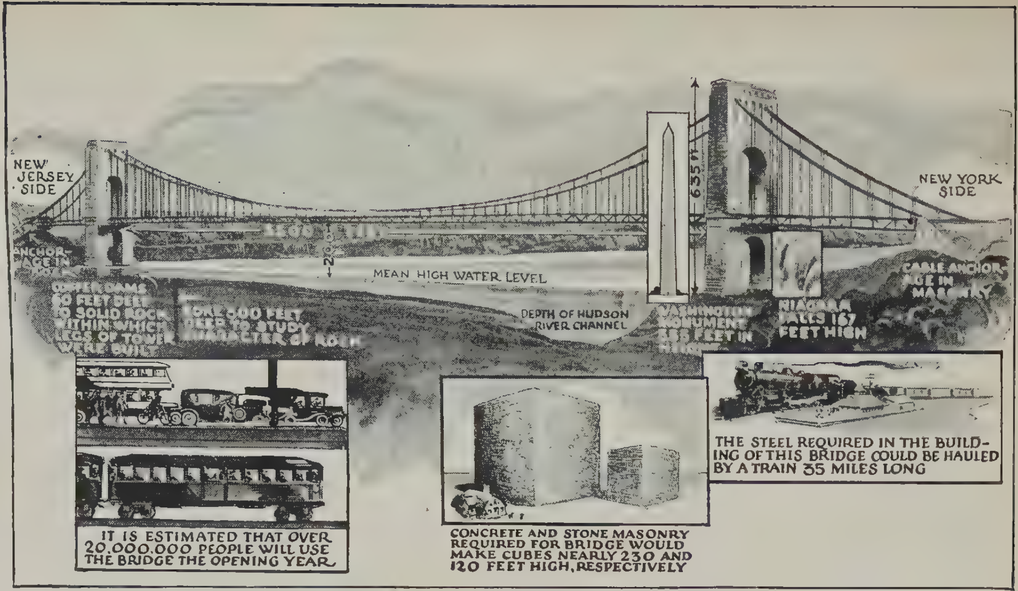

NEW JERSEY SIDE
NEW YORK SIDE
ANCHORAGE IN ROCK
MEAN HIGH WATER LEVEL
DEPTH OF HUDSON RIVER CHANNEL
635 ft
COFFERDAMS 90 FEET DEEP TO SOLID ROCK WITHIN WHICH LEGS OF TOWER WERE BUILT
FEET DEEP TO STUDY CHARACTER OF ROCK
WASHINGTON MONUMENT FEET IN HEIGHT
NIAGARA FALLS 167 FEET HIGH
CABLE ANCHORAGE IN MASONRY
IT IS ESTIMATED THAT OVER 20,000,000 PEOPLE WILL USE THE BRIDGE THE OPENING YEAR
CONCRETE AND STONE MASONRY REQUIRED FOR BRIDGE WOULD MAKE CUBES NEARLY 230 AND 120 FEET HIGH, RESPECTIVELY
THE STEEL REQUIRED IN THE BUILDING OF THIS BRIDGE COULD BE HAULED BY A TRAIN 35 MILES LONG

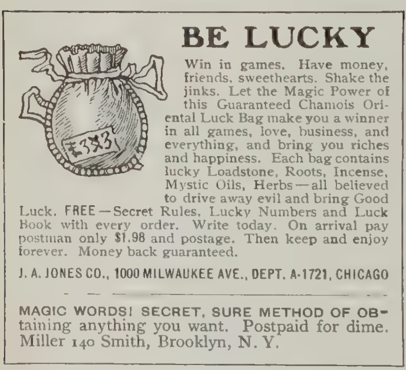
FIG. 4. NEW YORK–NEW JERSEY–HUDSON RIVER BRIDGE

This bridge (to be opened in 1932), costing about sixty million dollars, was made possible by combining many branches of science. What scientific attitudes did those who planned it need to have? What sort of knowledge about materials? Why is exact measurement necessary in such a plan?

have been possible because man has learned to measure with great accuracy. For example, there are machines with which you could measure distances shorter than the thickness of this page. In every well-equipped chemical[1] laboratory are scales so accurate that you could weigh a pencil mark with them. The wonders of modern engineering, mechanics, and science would have been impossible without extreme accuracy of measurement (Fig. 4).

6. Science depends also upon the right use of imagination. The great canals, the wonderful bridges and tunnels, the beautiful cathedrals (Fig. 186, p. 326), the towering buildings, each existed first in someone's imagination. Imagination alone produces no great results. Great works like these are possible only when imagination is combined with knowledge and use of materials, with scientific attitudes, and with exact measurement.

SCIENTIFIC PUZZLES AND GAMES



BE LUCKY

Win in games. Have money, friends, sweethearts. Shake the jinks. Let the Magic Power of this Guaranteed Chamois Oriental Luck Bag make you a winner in all games, love, business, and everything, and bring you riches and happiness. Each bag contains lucky Loadstone, Roots, Incense, Mystic Oils, Herbs—all believed to drive away evil and bring Good Luck. FREE—Secret Rules, Lucky Numbers and Luck Book with every order. Write today. On arrival pay postman only $1.98 and postage. Then keep and enjoy forever. Money back guaranteed.

J. A. JONES CO., 1000 MILWAUKEE AVE., DEPT. A-1721, CHICAGO

MAGIC WORDS! SECRET, SURE METHOD OF OBtaining anything you want. Postpaid for dime. Miller 140 Smith, Brooklyn, N. Y.

FIG. 5. WOULD YOU BUY THESE?

1. How many of the scientific attitudes can you discover in the story at the beginning of this chapter?

2. This sort of advertising (Fig. 5) is often found in a certain type of magazine. Would a scientist buy the "Guaranteed Chamois Oriental Luck Bag" or the "Magic Words"?

---

[1] *Chemical* (kem'i kl): having to do with chemistry, which is the study of substances for the purpose of finding out what they are made of and how they act. A *chemist* is a scientist who knows and uses chemistry.

Justify your answer by quoting one or more of the scientific attitudes.

3. Make a list of all the superstitious beliefs and sayings you can think of, such as carrying a rabbit's foot for good luck, knocking wood, "A four-leafed clover brings good luck," "Thirteen is unlucky," "Potatoes should be planted in the dark of the moon."

4. Problems 1, 2, and 3 are scientific puzzles to test whether you have some of the scientific attitudes. After the statement of the problem, you will find five opinions, or answers. See whether you can pick out the best one in each case; that is, the one which a carefully trained scientist would consider best. Then see whether you can find which of the scientific attitudes is illustrated by the problem and the best answer.

Problem 1. A new kind of fruit jar is advertised. A woman decides to give it a trial and buys one. The fruit she cans in it spoils, and she therefore concludes that the new jar is not a success.

a. There is no doubt whatever that she is right in her conclusions.

b. She is probably right, but perhaps she shouldn't decide after only one trial.

c. She is just about as likely to be wrong as she is to be right, because it isn't scientific to make a conclusion after only one trial, or experiment.

d. She is more likely to be wrong than right, because people do not advertise fruit jars or other things that are not first class.

e. She is probably wrong, because the jar in which fruit happens to spoil is "the exception that proves the rule."

Problem 2. A few years ago a famous traveler whom all the great scientists considered a first-rate scientist stated that he had found in South America a bird which had a head something like a lizard's and a tail something like a parrot's, and which cracked and ate nuts. Nobody else had ever reported having seen or heard of such a creature.

a. I will not believe the account until I see the bird.
b. The account might be true, but is not very likely to be.
c. It couldn't possibly be true.
d. It might be true, and probably is, if a first-rate scientist said so.
e. There can be no doubt whatever that it is true, because a first-rate scientist never makes mistakes.

Problem 3. Suppose you have just tossed up a coin four times and it has come down "heads" every time; that is, it has come down "heads" four times in succession. If you should toss it up again

a. It would probably come down "heads" again.
b. It would be certain to come down "tails."
c. It would be more likely to come down "tails" than "heads."
d. It would be just as likely to come down "heads" as "tails."
e. It would be very much more likely to come down "tails" than "heads."

Suppose you experiment to find out which is the correct answer. Assume that you have already tossed up a coin four times and that it has come down "heads" every time. Then actually toss up a coin to see whether it comes down "heads" or "tails" the fifth time. Try this again a number of times until you find out which of the five answers is the correct one.

UNIT II. AIR AND MAN'S USES OF IT

CHAPTER II

WHAT THE AIR MEANS TO US

Some Questions this Chapter Answers

How high does the air extend? What is a barometer? How is it made? How is it used? In what sense is the air a blanket round the earth? How is the air used in transportation? How has the air been explored higher than men can go? What are some of the most important events in the history of riding on the air?

To the Teacher and Pupil. Each pupil is expected to learn thoroughly, that is, to master, the material in all the paragraphs marked "*". Each pupil is expected also to master as much of the material as the teacher may assign in the paragraphs marked "†" and in those which are not marked. The materials are thus organized so that teachers who wish to do so may assign work on three levels to meet the needs of individual pupils.

7. Extent of the atmosphere. It is sometimes said "The air is everywhere." Is this strictly true?

Experiment 1. Is there air in soil? Put a lump of solid soil several inches thick into a vessel of water. Do you observe anything which enables you to find out whether there was air in the soil? The results would be the same, but not so striking, if a porous[1] rock or piece of wood were used in this experiment.

Experiment 2. Is there air in water? Heat a pan of cold water. Does anything occur which enables you to prove whether there was air in the water?

†Those who have been on high mountains or in airplanes (Fig. 6) have noted that the air seems less abundant at great heights. No one knows exactly the extent of the atmosphere, but its depth above the earth's surface is estimated to be something more than two hundred miles. Estimates regarding meteors (see page 283) show that there is air enough two hundred miles or more from the earth's surface to cause the meteors to become red-hot at least that far away.

The air penetrates[2] almost all other substances. Also the air is so light that it moves very readily and rises to great heights. These facts regarding the nature of air also help to explain the common observation that air is almost always in motion.

Are there any winds at a height beyond the atmosphere? Why have men been unable to measure the exact height of the atmosphere?

8. Is the air heavy as well as light? When we say anything is light, we usually mean that it is lighter than something else; that is, that it weighs less, volume for volume, than something else. We do not mean that the light substance has no weight.

Air has weight. Would it be heavier near the surface of the earth than at the top of a high mountain?

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[1] *Porous* (por′ us): A substance is porous if it has many small holes through it, as bakers' bread.

[2] *Penetrate* (pen′e trate): to pass into or through.

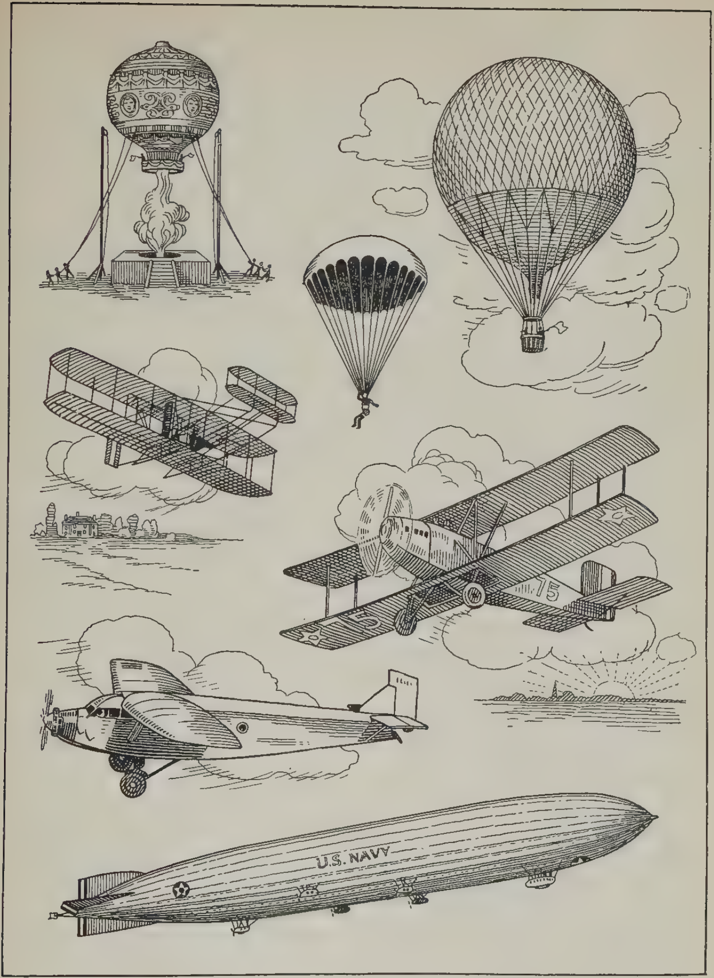

FIG. 6. RIDING ON THE AIR

The first balloon; modern balloon with parachute; the first Wright airplane; a modern biplane; a modern monoplane; a dirigible balloon

†A device for weighing the air was invented in 1643 by an Italian physicist[1] named Torricelli.[2] Torricelli's teacher, Galileo,[3] another famous Italian scientist, had been trying to learn the "power of a vacuum."[4] He had concluded that it is not a vacuum that causes water to rise in a so-called "suction pump" (Fig. 12, p. 30), but the pressure of air. When Galileo died, Torricelli went on with the experiments. The device he made was called a barometer, which means "weight measure." This scientist thought he could use a tube of glass filled with mercury to find one way of learning how much downward pressure the air has. He sealed the glass tube so that one end was entirely closed. He then filled the tube with mercury. Mercury is heavy, since it weighs 13.6 times as much, volume for volume, as water. Torricelli probably thought to himself: "If I can invert[5] this glass tube, filled with mercury, so that the open end will be within a dish of mercury and below its surface, I'll find out whether the pressure of the air will keep the mercury from flowing out of the tube, for there is no air in the tube to push the mercury out. If only part of the mercury flows out, I'll know that the amount remaining in the tube is the amount which the air pressure can hold up." So he placed a finger tightly over the open end of the glass tube, inverted it into a dish of mercury (Fig. 7), then took his finger away. Some of the mercury flowed into the dish, but not all of it. This left in the closed upper part of the tube a small

---

[1] *Physicist* (fiz'i sist): one who studies the science of forces and forms of energy.

[2] *Torricelli* (tor e chel'le): the inventor of the earliest barometer.

[3] *Galileo* (gal i lay'o): one of the world's greatest scientists.

[4] *Vacuum* (vak'u um): A perfect vacuum would be a space in which there is nothing whatever. It is common, however, to use the terms "vacuum" or "partial vacuum" for a space from which part of the air has been removed.

[5] *Invert* (in vert'): to turn upside down.

space or vacuum in which there was no air and no mercury. The column of mercury in the tube reached about thirty inches above the level of the mercury in the dish.

*Later experiments by many students proved that at sea level the mercury column will always stand about thirty inches high when this experiment is performed in this way. The weight of the air exerts a pressure which has been determined and found to be about fifteen pounds per square inch. Sometimes the weight of air at different places varies because of changes in the content and movements of the atmosphere itself. The weight of air at any place is most commonly spoken of as the air pressure at that place.

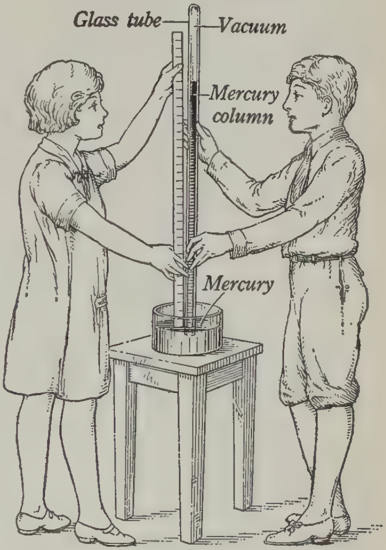

FIG. 7. MAKING A BAROMETER

9. *Air pressure varies at different heights. On the basis of many experiments like those described in the preceding section, accurate barometers have been made. Those commonly used are called aneroid[1] barometers and may be about the size of a large watch. They measure air pressures directly and do not use a mercury tube. By use of them air pressures at different levels have been measured. At sea level the pressure is recorded as about thirty inches; it is only about half that amount at three miles above sea level (Fig. 8). One might argue that by going a little more than twice three miles above sea level there would be no air pressure; but aviators[1] have accomplished the feat of flying more than eight miles high and have found air enough to support them.

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[1] *Aneroid* (an′er oid): getting along without liquid. The word is not used except in naming one kind of barometer.

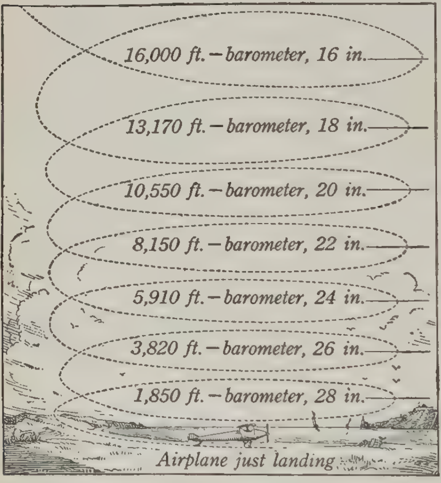
16,000 ft. – barometer, 16 in.
13,170 ft. – barometer, 18 in.
10,550 ft. – barometer, 20 in.
8,150 ft. – barometer, 22 in.
5,910 ft. – barometer, 24 in.
3,820 ft. – barometer, 26 in.
1,850 ft. – barometer, 28 in.
Airplane just landing

FIG. 8. THE AVIATOR WORKS IN CHANGING PRESSURES

†One type of aneroid barometer gives a permanent record of air pressure. It is equipped with a pointer in the form of a pen. The point of this pen rests upon a special record sheet marked off in twenty-four equal spaces to represent the hours in a day. This record sheet is fastened to a cylinder which makes a complete revolution in twenty-four hours. The pen is placed on the paper at the line representing the hour when the cylinder is started revolving. As the cylinder slowly revolves, the pen marks a crooked line on the paper, moving up or down as the air pressure, as registered by the aneroid, changes. A second scale on the paper enables one to read the pressure which the pen registers for any hour in the day. The United States Weather Bureau uses this type of aneroid barometer. Why?

---

[1] *Aviator* (a′vi a tor): one who flies in an airship.

†These measurements of air pressures have been made so often and studied so carefully that barometers are now used to determine heights. A mountain climber or an aviator reads the air pressure in inches on his aneroid barometer, then finds from tables the height which agrees with that pressure. Many important aspects of modern study and travel in the air would be impossible without the use of barometers. Many famous airplane flights have been made in part through fogs and rain, and over the ocean when no land could be seen. At such times the aviator must depend upon barometers and other instruments to guide him.

10. The air and temperature. Almost all the earth's heat comes from the sun. The heat waves, or rays, from the sun pass through the space between the sun and the earth without heating that space. They also pass through the air to the earth. The air is warmed partly as the heat comes to the earth and partly as heat rays are reflected by the earth. The air serves as a blanket to hold heat which has reached the earth in this way. If this blanket of atmosphere were not round the earth, the daytime heat would be too great for life upon the earth and the cold at night would be too severe to permit life to exist.

Mountain climbers and aviators who have gone four and five miles high find that as the air becomes thinner the cold increases. Indeed, one of the difficulties in altitude[1] flying is due to the severe cold. Under average conditions the temperature decreases about 4 degrees for each one thousand feet rise above the first half mile. When the temperature on the ground is 60° F., zero temperature would be encountered between three and four miles high. Estimates have been made which of necessity

[1] *Altitude* (al'ti tude): the height above sea level.

cannot be absolutely proved as yet, that the temperature of space beyond the atmosphere is probably about 459° below zero Fahrenheit. This cold space through which our heat rays come from the sun offers opportunities for one's imagination. It is probable that in the future scientists will be able to find out much more about this region which is now beyond our accurate knowledge.

In 1910, at Huron, South Dakota, Mr. William R. Blair sent a balloon (Fig. 6, p. 17) up to a height of 18.95 miles. The recording instruments had been attached to a parachute.[1] These instruments were self-acting, so that they made records even though no human being was with the balloon. At the height given, the thin air and the outward pressure of the gas in the balloon caused the balloon to burst, but the instruments and records were recovered in good condition.

11. Riding on the air. In the British Science Museum, London, the Wright Brothers' original airplane (Fig. 6) is almost constantly being viewed by its procession of visitors. These quiet and thoughtful brothers had long been studying the flight of birds and wondering how men could fly. If most persons made fun and said, "You can't fly through the air," the reply could always be, "But birds do; why can't we?" After many years of hard work amid great disappointments, in 1903 these brothers completed the first successful airplane, and on December 17 of that year they succeeded in making four flights, the shortest of 12 seconds, and the longest of 59 seconds. This was a day of great promise. In 1911 Glenn Curtiss produced his first hydroplane.[2] Since that time astonishing progress has been made. Some of the more striking feats of aviators are listed below, and news reports will provide much information to add to this list. The list is not complete but is interesting.[1]

---

[1] *Parachute* (pair′a shoot): an umbrella-like device used in descending from airplanes and balloons.

[2] *Hydroplane* (hi′dro plane): an airplane which rises from water and lands on water.

1905. Orville Wright made a flight of 12.12 miles in 19 minutes 55 seconds at Dayton, Ohio.
1907. Henri Farman, Frenchman, made a flight of 2530 feet in 52.5 seconds.
1908. Farman made the first recorded flight carrying a passenger.
1908. Orville Wright made a flight of an hour, carrying a passenger.
1908. Wilbur Wright attained an altitude of 360 feet at Le Mans, France.
1909. Blériot, Frenchman, flew across the English Channel from Calais to Dover in 37 minutes.
1909. Farman flew 145 miles at a speed of 35 miles per hour.
1910. Fabre, Frenchman, made the first successful flight rising from water.
1910. Glenn Curtiss flew from Albany to New York City, 143 miles, in 2 hours 50 minutes.
1910. McCurdy received and sent messages from an airplane at Sheepshead Bay, New York.
1910. Legagneux, Frenchman, claimed the world's altitude record with a height of 19,171 feet.
1911. Ely flew from the shore near San Francisco, landing on the deck of the battleship *Pennsylvania*; then flew back to the shore.
1918. The first regular air-mail service was established between New York and Washington.
1919. White made the first nonstop flight between New York and Chicago, 727 miles.
1919. Rohlfs made the American altitude record, 34,610 feet.

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[1] Records taken from Aircraft Year Books.

1923. Kelly and Macready made a nonstop flight from New York to San Diego, 2516 miles, in 26 hours 50 minutes.
1926. Byrd flew from Spitzbergen to the north pole and back in 15 hours.
1926. Amundsen and others flew in a dirigible from Spitzbergen to Teller, Alaska, 2700 miles.
1927. Lindbergh made a nonstop flight from New York to Paris, 3610 miles, in 33 hours 30 minutes.
1928. Eckener and others flew in a dirigible from Germany to the United States, carrying mail and passengers.

12. ***The air a supporting substance.** It has been difficult for people to understand that the air is all about us even though it cannot be seen. It may get in our way at times, as when the winds strike us, or it may be used by us as when it is made to carry airplanes or balloons (Fig. 6, p. 17) or dirigible airships. Such machines really ride within and upon the air, and are held up by it. Just as one must keep moving when he swims in water, so in the air the airplane must keep moving rapidly in order to cause the air to support it.

*Balloons and dirigible airships are filled with gases of which a given volume is lighter than the same volume of ordinary air. Since they are lighter the heavier air about them flows under them and pushes them up. They are lifted to a height where the surrounding air weighs about the same, volume for volume, as the gas within the balloon. Dirigibles can be made to rise higher by throwing out ballast,[1] such as sand or water. They can be made to descend by letting out part of the gas. In the most modern dirigibles engines are used to help the airship to climb or descend.

*We should think of the air as a deep sea of gas entirely surrounding the earth and sometimes flowing one way, sometimes another, and sometimes remaining quiet.

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[1] *Ballast* (bal′ ast): sand or stones placed in a boat to make it steady.

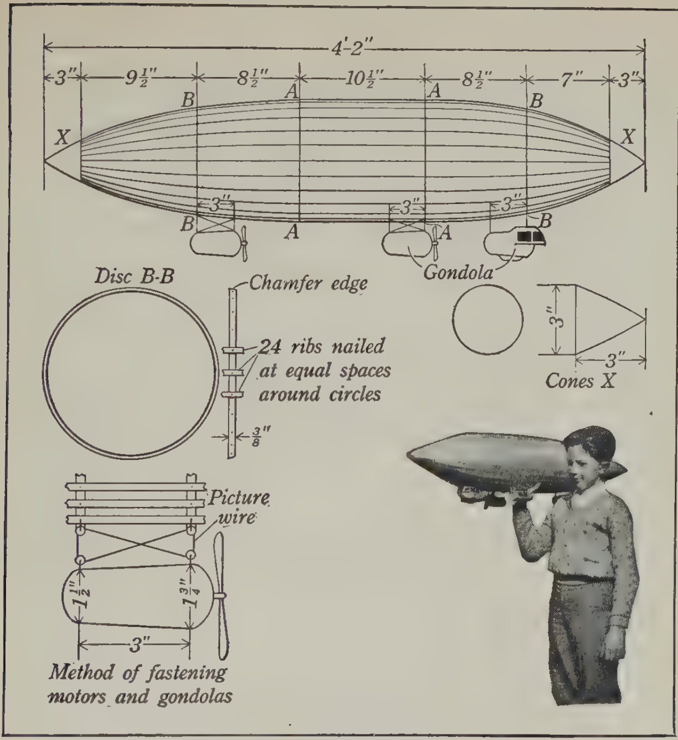

FIG. 9. A MODEL DIRIGIBLE

Project.[1] To make a model dirigible. Here are a picture and diagrams[2] of a model dirigible (Fig. 9) which an eighth-grade boy made. Can you make one like it?

Special Report. From the nearest flying field secure facts by which to prepare a class report or discussion of conditions and rules which govern airplane flying in your vicinity.

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[1] This project was suggested by Mr. Marshall Byrn.

[2] *Diagram* (di′a gram): an outline drawing; to represent some object by means of a simple outline sketch.

TESTS AND GUIDES FOR STUDY AND REVIEW

The numbered statements are about the materials found in the starred topics in this chapter. Some of these statements are true and some are false. Can you pick out those which are true, and can you make each of the false ones true by changing one word? Here are two examples:

> Air completely surrounds the earth. (*This statement is true.*)
> The first barometer was made by Edison. (*This statement is false, but it can be made true by changing the word "Edison" to "Torricelli."*)

1. Air pressure at sea level will hold up a column of mercury about thirty inches high in a barometer.
2. The mercury column in a barometer would be higher on a mountain than in a mine.
3. The air pressure becomes gradually greater as one ascends above the earth's surface.
4. Airplanes and dirigibles travel in and upon the air in much the same way that submarines travel in and upon the water.
5. If the engine of a flying airplane stops, the airplane must descend at once.
6. An aviator flying three miles above the earth has about as much air above him as he has below him.

CHAPTER III

DOING WORK WITH AIR

Some Questions this Chapter Answers

Can we make the air remove the dirt which it has carried into our homes? What do we mean by suction? Can we change the amount of air in a given space? What is the difference between compressed air and a vacuum? What are some ways in which compressed air is used? How may air pressure be made to pump water? How is air used to enable men to work under water? How does air hold up an automobile? How is air made to carry articles in stores, factories, and elsewhere?

13. Moving things in the air. After a day of strong wind we often find dust upon books, windows, furniture, and floors, and even upon our clothing. What do we mean by a strong wind, and how does it affect the dust? Can the wind which helps to put dust into our homes be made to take it out?

Experiment 3. Can you make a wind with a medicine dropper? Cut some paper into very small pieces, then hold the open end of a medicine dropper close to the pieces (Fig. 10). Press and release the rubber bulb and see what happens to the paper. Can you drive the paper away or pick it up, as you wish? When you have picked up a piece of paper on the end of the medicine dropper, can you hold the paper as long as you wish by use of the bulb? How must the bulb be used to pick up and hold a piece of paper? Why?

*A vacuum cleaner (Fig. 11) is a sort of manufactured wind machine. The electricity makes the motor run. The motor forces the air through the dust bag. The air, rushing into the open end of the sweeping tube, carries dust with it. The walls of the dust bag are of finely woven cloth — so fine, indeed, that the air can pass through it but the dust cannot. The particles[1] of dust are very small, but the molecules of air are very much smaller. Indeed, the air molecules are so small that they are kept from passing through only by solid substances.

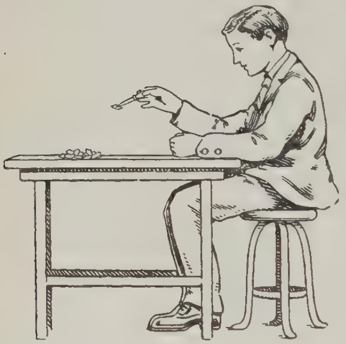

FIG. 10. EXPERIMENTING WITH THE AIR

*When anything occurs which takes the air away from one place, the air round about flows in because of its greater pressure and takes the place of the air that was removed. Thus, when the bulb of the medicine dropper is pressed, the air within is removed. When the pressure is released, air flows into the bulb again. In a similar way the motor of the vacuum cleaner drives the air out of the cleaning tube and through the dust bag, thus forming a partial vacuum within the tube. Other air flows into the open end of the tube and then to the bag. When the air flows into the vacuum cleaner, it carries with it any substances which are light enough to be carried by the air current. The small pieces of paper used in the experiment with the medicine dropper start with the air current, but since they are too large to enter the dropper tube they adhere[1] to its end as long as the current of air flowing in is strong enough to hold them. The dust and other small substances with it are held within the dust bag. Thus the air which is a means of distributing dust can also be made a means of removing it.

---

[1] *Particle* (part′ i kl): a very small bit of anything.

14. *Suction a push and not a pull. Many people believe that the word "suction" means that something is being *pulled* into a space; but this idea — that sucking is drawing or pulling — is not correct. Whenever there is suction a partial vacuum is always formed into which the outer air pressure *pushes* something. The more nearly perfect the vacuum, the stronger the push of the air in the direction of the vacuum, because the diminished air pressure within the partial vacuum cannot push back so hard. It is not sensible to think that a perfect vacuum, which would be a space containing nothing whatever, could *do* anything. Air pressure outside the vacuum, however, could push something into the space in which there was no opposing pressure.

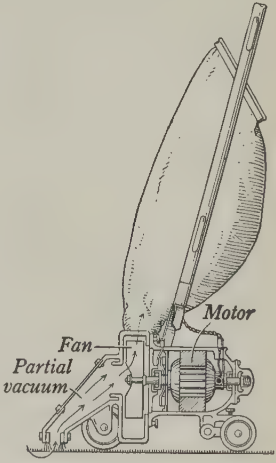

FIG. 11. THE VACUUM SWEEPER USES AIR TO REMOVE DUST

You can easily prove these facts with an air pump and bell jar of the types shown in Fig. 12. Tie a sheet of rubber dam, such as dentists use, *tightly* over the smaller, open end of the jar. Cover the surface of a glass plate with plenty of vaseline, then press the plate firmly over the dam so that no air can get under the edge of the plate. The plate holds the air outside the jar away from the dam, while the dam is not protected in any way from conditions inside the jar. Exhaust the air from the jar by use of the air pump. A partial vacuum is now formed in the jar, but this partial vacuum does not pull the dam down into the jar: the dam remains as it was. Now slide the glass plate off the dam. As soon as the outside air pressure, which has been supported by the plate, strikes the dam, it pushes the dam down into the partial vacuum in the jar. Thus we prove that suction is a push and not a pull, as many people believe.

---

[1] *Adhere* (ad here′): to stick to, as a stamp *adheres* to an envelope. *Adhesion* (ad he′zhun): act of adhering.

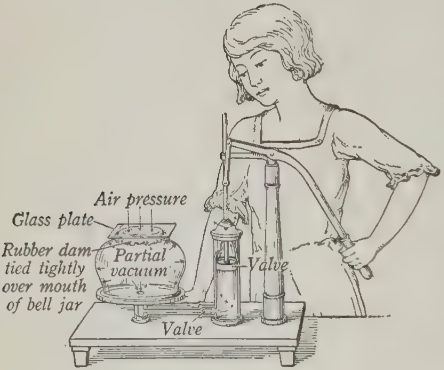

FIG. 12. AIR PUMP

Suction is a push and not a pull. Can you explain how the valves of the air pump operate?

15. *Uses of compressed air. Compressed[1] air is the opposite of a vacuum, since instead of removing air from a closed space, we pump more air into the space than it holds when open.

Project. To make a compressed-air gun. Secure a large quill (Fig. 13) from the wing feather of a goose, turkey, or chicken. Cut the feather smoothly so that

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[1] *Compress* (kom pres′): to squeeze together or to press into a smaller space. *Compression* (kom presh′un): the state of being compressed.

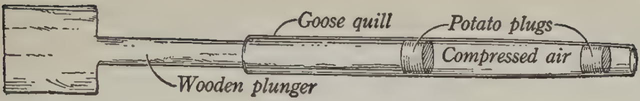

FIG. 13. POTATO GUN
A gun that uses compressed air

you have a piece of the base of the quill three or four inches in length and open at both ends. Make a wooden plunger (Fig. 13) which fits loosely within the quill and is at least two inches longer than it. Cut a slice of raw potato about an eighth to a quarter of an inch thick. Force the larger end of the quill through the slice of potato so as to cut a piece of the potato. With the plunger push this piece almost through the quill to its smaller end. Cut a second piece of potato in the same way. With the plunger push the second piece through the quill. Describe and explain what happens. Was the air crowded into one half, one third, or even less space before the potato was expelled? Shoot the piece of potato into the palm of the hand to see how much force is exerted when the compressed air is released.

†Airguns are constructed on the same principle as the popgun just discussed. Within the airgun is a plunger which when pressed down with great force compresses the air within the gun. When the gun is fired, the compressed air is released. It expands with striking suddenness and drives the bullet with such force as sometimes to be dangerous if used carelessly. Indeed, the wrong use of the compressed-air gun is objectionable,[1] as is the wrong use of any other scientific invention or application of scientific knowledge.

---

[1] *Objectionable* (ob jek′shun a bl): something which is not desired because it is unpleasant or harmful.

†When compressed air can be released very slowly, an air jet is made which may be used, as is done in such devices as the barber's hair-drying machine and the automobile-tire filler. This jet may also be made to spray paint upon houses, automobiles, or furniture. Sand may be the load carried by the air jet, and may be used in smoothing cast-iron surfaces or in cleaning the outside walls of city buildings. In the use of air brakes compressed air is applied to the brake and holds it against the wheel. The familiar shrill whistling sound that follows the use of air brakes is caused by the escape of the compressed air when the brake is released. Thus air can be made to stop trains and street cars.

†When men must work under water, as in building foundations for bridges or dams, compressed air may be used to hold the water back while work proceeds. Heavy walls called caissons (Fig. 14) are so constructed that air may be compressed enough to keep out the water more than a hundred feet below the surface. The men who are to work in these caissons cannot withstand too sudden changes from air of one pressure to another. There is air in the human body — in the blood, in the lungs, in the ears, and, to some extent, in other parts of the body. If the outside pressure were to become doubled too suddenly, this air pressure might injure the eardrums. If the pressure of the outside air were suddenly to become half as great, the air within the ears would push outward, causing similar injury. When the air pressure on the outside of the body is greatly increased, air is forced into the blood and other body liquids. If later the air pressure is suddenly reduced, the air in the liquids forms bubbles which may cause serious illness. Therefore when caissons are needed for work under water, use is made of

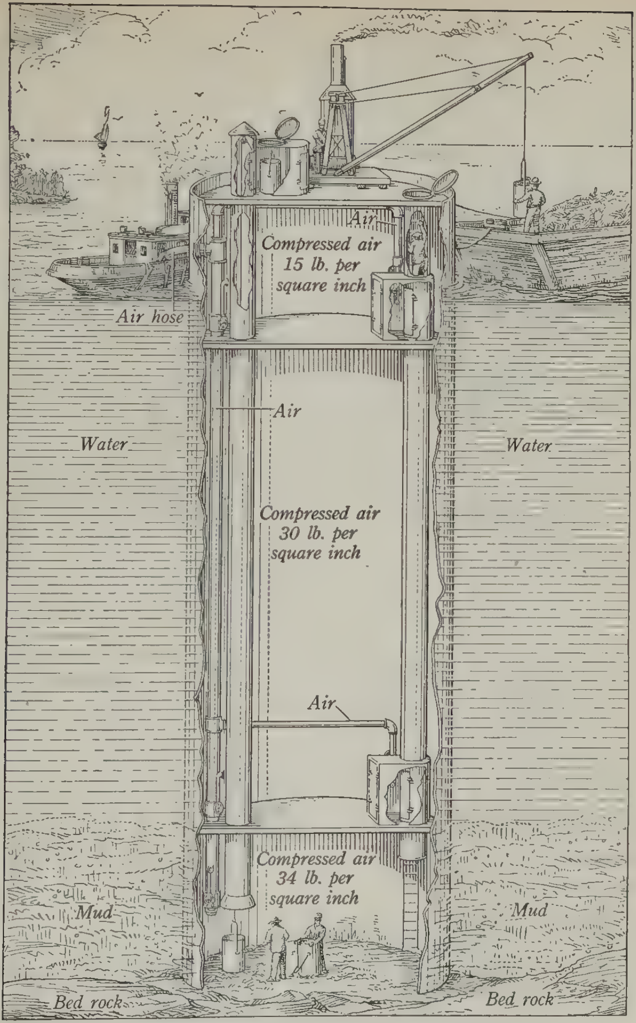

FIG. 14. DIAGRAM OF A CAISSON

Why is greater air pressure required within the caisson in deep water than in shallow water?

several small compartments,[1] each capable of being closed from the others. By use of this series of small rooms graded air compressions may be provided so that the workmen may become adjusted[2] gradually to the different air pressures; that is, so that air pressures may become equal inside and outside the men's bodies.

†The earliest rubber tires for bicycles and carriages and even some of the first tires for automobiles were of solid rubber. It was a long time before hollow rubber tires could be made to hold air with enough compression to support the vehicle.[3] In a flat tire the supporting compression of air has been lost.

> What is the amount of compression of air ordinarily required in some of the common automobile tires? How is it secured? What pressure is used in bicycle tires? Why is the use of hand pumps for compressing air in automobile tires not commonly favored? What advantages has the balloon tire over earlier types?

There are many other common examples of the use of compressed air, the amount of compression depending upon the uses to which it is put. Air drills are widely used in mining and in various types of construction work. In the air door-check (Fig. 15) the air is compressed as the door closes and is released as it opens. Life belts, pillows, cushions, many kinds of devices, may be listed among the uses of compressed air.

> *Special Report.* Find out how many applications of compressed air are used in your community. Can you explain how these devices operate?

---

[1] *Compartment* (kom part′ment): one of several divisions, as the drawers of a desk or a filing cabinet.

[2] *Adjust* (ad just′): to make suitable; to fit as one thing to another.

[3] *Vehicle* (ve′hik l): any carriage or means of transportation.

16. *Pumping water with air pressure. Many homes secure their water supply by means of what is commonly called a lift pump, or sometimes, incorrectly, a suction pump. A pipe or pump stock extends into the water supply in the well (Fig. 16). The main body of the pump fits tightly into the upper end of the long stock. There is a valve[1] at the bottom of the main body of the pump. Within this main body is another valve (Fig. 16, *A*), attached to a piston which is raised and lowered by the pump handle. When the pump handle is raised, the piston is pushed downward within the pump; when the handle is lowered, the piston is raised. The valves are so arranged that the upper one is forced open when the piston is lowered, and is forced shut when it is raised. The lower valve is closed when the upper one is open and is open when the upper one is closed. As the pump handle is raised the piston goes downward (Fig. 16, *B*), the piston valve is forced open, and the lower valve is forced shut. If there is water standing above the lower valve, it will then flow through the upper valve. When the piston is raised, the upper valve

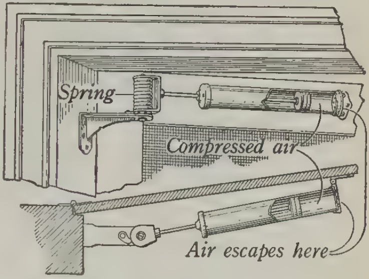

FIG. 15. DIAGRAM OF A DOOR-CHECK

The coiled spring pulls the door shut. As the door closes, the cylinder is pushed farther into the piston and compresses the air. The compressed air escapes through holes in the end of the cylinder, allowing the door to close softly. What would happen if the cylinder were air-tight and no air could escape around the piston? Explain. Would a door-check operate in a vacuum? Explain

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[1] *Valve* (valv): a device within a pipe or tube by means of which the passage is closed or opened.

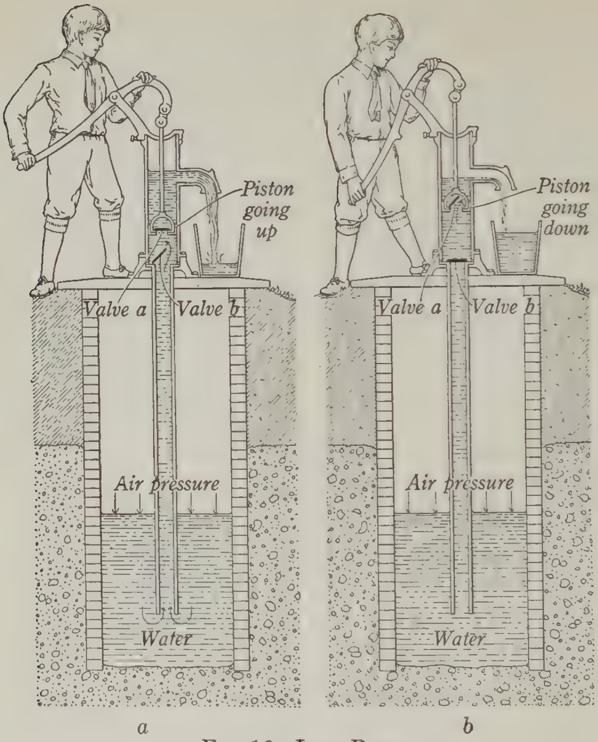

FIG. 16. LIFT PUMP

Using air pressure to raise water

is forced shut and carries its load of water up and pours it out. The lower valve, which is now open, admits a new supply of water that is pushed upward through it, filling the space between the two valves. The ordinary pressure of the air at sea level cannot cause water to rise more than about thirty-four feet. Because of friction[1] the pumps rarely lift the water more than twenty-seven or twenty-eight feet. Explain (using Fig. 16, *a* and *b*) what causes the valves to open and close as the piston goes up and down.

---

[1] *Friction* (frik′shun) : the opposition to the movement of one body against another.

*The force pump differs from the lift pump in that it is constructed to throw water out of the pump, not merely to have it flow out. This is accomplished by arranging the valves as in Fig. 17. The piston attached to the pump handle has a solid disk[1] which fits tightly within the pump cylinder. The valve at the bottom of the pump cylinder is forced shut as the piston is pushed downward and is forced open as it rises, as in the lift pump. The outlet pipe is equipped with an air chamber. As the piston descends, water is forced into the air chamber; as the piston rises, the pump cylinder is again filled with water. When the piston forces the water into the outlet pipe faster than it can escape, some of the water is forced into the air chamber and compresses the air. While the piston goes upward, the compressed air keeps the water flowing steadily through the spout.[2] If the air chamber is large and the outlet or spout is kept closed until the pump has produced a high degree of compression, a strong jet or current or spray of water may be

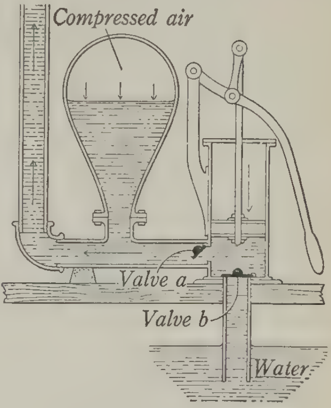

FIG. 17. FORCE PUMP

Using compressed air and air pressure to raise water. Can water be raised to a greater height with a lift pump or with a force pump? Explain thrown. It is upon this principle that sprays and fire-engine pumps have been constructed.

---

[1] *Disk:* a flat circular piece of material.

[2] *Spout:* a tube or trough through which to pour a liquid from a vessel; to shoot out in a jet.

Special Report. Diagram and explain the action of a fire-engine pump.

17. † Transportation by air pressure. In stores it is common to see the clerk put his sales slip and cash into a small rubber cylinder, open a valve in the side of a tube, and put in the cylinder (Fig. 18). The valve snaps shut with a sharp sound. Soon the cylinder, with its stamped slip and change, returns and drops into the clerk's basket. Air is pumped into one end of the tube and out of the other end. The cylinder fits the tube tightly so that there is compressed air on one end of it and a partial vacuum on the other. It is the air pressure which pushes the cylinder to the central office and back. In modern stores extensive systems of air tubes carry large sums of money and hundreds or thousands of messages and articles of merchandise. This work is done with a speed and safety not possible under the former system of boy and girl messengers.

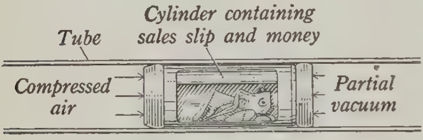

FIG. 18. DIAGRAM OF CASH-SALES CYLINDER

Compressed air forces the cash cylinder toward the partial vacuum

†In large cities the post-office departments use air tubes for transporting cylinders containing mail bags from one division to another within the city. In this way the mail not only is carried much more rapidly but probably is less likely to suffer accident or loss than when carried by vehicles. It must be kept in mind, however, that any

such useful application of knowledge depends upon the intelligence, understanding, and proper actions of the human beings who are in charge.

TESTS AND GUIDES FOR STUDY AND REVIEW

Most of these statements are like those at the end of Chapter II; that is, true or false. Can you pick out the true ones and correct the false ones by changing not more than two words? Can you fill the blanks in the remaining statements so that these statements are correct?

1. A space from which part of the air has been removed is called a partial ____.
2. A vacuum sweeper would do its work better in a valley home than in a mountain home.
3. The vacuum sweeper removes dust by making the air ____ less inside the "suction" end of the sweeper than it is round the sweeper.
4. When you drink lemonade through a straw, you first make a partial vacuum in your mouth. The lemonade is then pushed into your mouth because the pressure of the air upon the lemonade in the glass is greater than the pressure of the air in your mouth.
5. Whenever there is suction, objects may be pulled into the partial vacuum, but are never pushed into it.
6. Compressed air is the opposite of a ____.
7. When you blow up a rubber balloon, the balloon is filled with compressed air.
8. Ordinary air pressure will hold up a column of water about ____ feet high.
9. Lift pumps are seldom able to lift water more than ____ feet.
10. A lift pump would do its work better on a hill than in a valley.
11. Water is lifted in the lift pump and the force pump by means of a vacuum.
12. The lift pump uses compressed air to make the flow of water steady.

CHAPTER IV

WHAT IS THE AIR?

Some Questions this Chapter Answers

Of what is the air made? How may oxygen be prepared for study? What is the nature of oxygen? How does oxygen cause explosions? How is the use of paint on buildings related to a knowledge of oxygen? What is the nature of carbon dioxide? What is the nature of nitrogen? How is water carried in the air? What kinds of dust does the air contain? What are the differences between physical and chemical changes? Describe the difference between elements, compounds, and mixtures.

18. *The air a mixture of several gases. Air consists of about 78 per cent[1] of nitrogen, about 21 per cent of oxygen, and about 1 per cent of argon. Carbon dioxide, water vapor, and other gases, including those escaping from factories, natural-gas wells, coal mines, cooking-rooms, and similar sources, are usually present in small quantities. Solid substances also, in the form of fine dust, are always to be found in the air, even at the highest altitudes at which it has been studied. Winds and altitudes are factors in the distribution of the gases and dust.

*It must be understood that the different parts of the air are not combined with one another, but are merely mixed together. Dust may be present only in a trace or in such large quantities as to form a dark cloud, but the amount of dust present is not known to affect the amount or the action of the gases of the air.

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[1] *Per cent:* the number of parts of every hundred parts; for example, 78 per cent means 78 parts of every 100 parts.

19. *Oxygen an active substance. In many respects oxygen is the part of the air which concerns us most, although it composes only about one fifth of the bulk of the air. It is easily the air's most active substance. We breathe air, but make direct use only of the oxygen we inhale.[1] In our lungs the oxygen is taken up by the blood, while carbon dioxide is taken from the blood and carried away by the air which we exhale.[2] We breathe in the nitrogen, but it is not known either to harm us or to be of use to us. The dust may be harmful, as will be shown later.

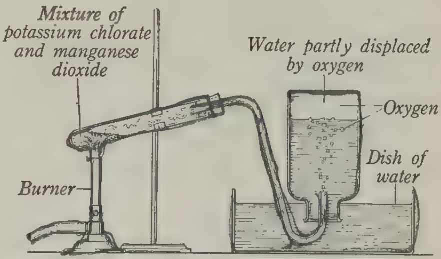
Mixture of potassium chlorate and manganese dioxide
Water partly displaced by oxygen
Oxygen
Dish of water
Burner

FIG. 19. PREPARING OXYGEN FOR STUDY

Since oxygen, like most gases, cannot be seen or taken in the hands, and since pure oxygen has no odor, we must learn about it by other means. Oxygen can be taken from the air for examination, but it is more easily secured in other ways. Substances which contain oxygen may be broken up in such a way that the oxygen is set free and may be caught and examined (Fig. 19). A common substance for this use is potassium chlorate, a substance which is sometimes used as a medicine for "sore throats."

Experiment 4. How may oxygen be prepared from other substances? Place a mixture of three parts of potassium chlorate and one part of manganese dioxide in a test tube, as shown in Fig. 19. A glass tube from within the test tube extends through the tightly fitting stopper, then beneath the surface of the water in a dish. The lower end of the tube is placed in the open end of an inverted water-filled bottle. As the mixture of potassium chlorate and manganese dioxide is heated gently, bubbles of oxygen pass through the glass tube and appear in the bottle. The bubbles crowd out the water as the gas is collected. Two or three bottles of oxygen should be collected for study. The oxygen may be kept in the bottle by placing a glass plate over the mouth of the bottle while it is still under the surface of the water. The bottle may then be placed upright upon the table.

---

[1] *Inhale* (in hale′): to breathe in. [2] *Exhale* (ex hale′): to breathe out.

*Pure oxygen has no taste or odor. If a piece of wood is lighted, the flame blown out, and the wood thrust into the oxygen before the coal on the wood has gone out, the action of oxygen in burning may be observed. Likewise if the end of a piece of iron picture wire is heated very hot and is thrust while still incandescent[1] into a jar of oxygen, its burning may be observed. In fact, *burning* and *oxidation* (which means *combining with oxygen*) *are the same process.* Most kinds of oxidation are slow. Oxidation by burning is rapid; indeed, burning or fires can always be prevented if the supply of oxygen can be kept from the burning substance. A good way to put out a small fire is to cover it with a blanket or with sand so that oxygen cannot get to it.

20. *Explosions result from extremely rapid oxidation. Substances such as gunpowder and dynamite contain chemicals which oxidize[2] readily. The oxygen used for this oxidation is contained in the substances, being stored in much the same way that oxygen is stored in potassium chlorate (Experiment 4, p. 41). When the gunpowder or dynamite is "set off," the oxidation takes place very rapidly — so rapidly indeed as to be dangerous. Gases are produced which expand[1] with powerful force. This rapid expansion of gases with violence is called an explosion, and the substance which produces the explosion is called an explosive. When properly used, such explosives may help by blasting masses of rock or stumps of trees (Fig. 20); when wrongly used, they may destroy buildings and human beings. When used in firearms, explosives may be the source of pleasure in gaining accuracy and control. They may also be the means of cruel destruction or an agency of war. Knowledge of science, like other knowledge, is good or bad, depending upon the uses to which it is put.

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[1] *Incandescent* (in kan des′ent): white-hot, or glowing with heat.

[2] *Oxidize* (ox′i dize): to combine with oxygen.

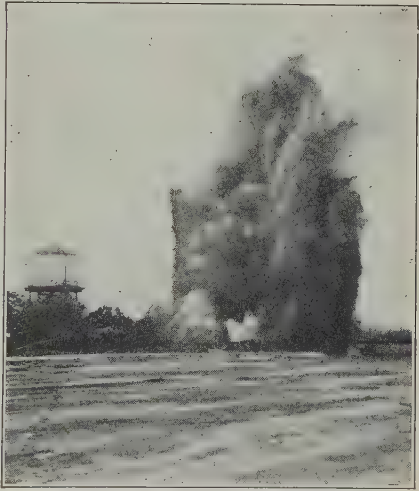

FIG. 20. RAPID OXIDATION MAY CAUSE AN EXPLOSION

Special Reports. From a book on chemistry learn about explosions of gunpowder, dynamite, and similar explosive substances. How many uses of explosives can you list?

---

[1] *Expand* (ex pand'): to swell out; to increase in volume. *Expansion* (ex pan'shun): the act of expanding.

Burning and explosions are examples of rapid oxidation. It is likely that more destruction is caused by slow oxidations than by the rapid oxidations which produce explosions. All about us are decaying materials slowly oxidizing and slowly becoming useless. The processes occur so slowly that they are usually not noticed. We can hear and see the explosion which tears down a building; we cannot hear and are not so likely to see the gradual oxidations of all kinds of property which is no less certainly being oxidized.

21. †Paint protects surfaces from oxidation. Many people think that the main reason for using paint is to make fences, houses, and the like look more attractive. Paint does make a building more beautiful, but that is not the chief reason for using it on the outside of the building. Its chief purpose there is to protect the surface of the building from oxygen and moisture in the air. Paint consists of a colored powder (called a pigment) mixed with oil, usually linseed oil. We hear the expression "paint dries." This "drying" is not really drying in the same sense that water dries — that is, by evaporation;[1] when paint dries, the oil oxidizes. This oxidized oil makes a tough film, or thin skin over the surface. This film holds the pigment to the surface, and the pigment helps the film to protect the surface by filling very small holes in the film of oxidized oil. "Driers" are substances which help to make the oil oxidize faster. They do this in the same way that manganese dioxide helped to make the oxygen come from the potassium chlorate faster in the oxygen experiment (see page 41) without undergoing any change, itself.

---

[1] *Evaporate* (e vap′or ate): to change a liquid or a solid into a vapor by heating. *Evaporation* (e vap o ra′shun): making a substance into a vapor.

Special Reports. Discuss the nature and uses of stains and varnishes, enamels, and thinners such as turpentine and benzol. Describe the preparation of whitewash and calcimine. How are colors mixed? How may paintbrushes be cleaned? Discuss the possible dangers from chemicals in paint and varnish.

22. *Carbon dioxide one product of oxidation. You are familiar with carbon dioxide as the gas which bubbles out of soda water. Although carbon dioxide is ordinarily found in air in small quantities (about 1 part in 3000 of air by volume), it is important in several ways. It is slightly heavier, volume for volume, than the rest of the air; consequently it tends to settle close to the earth's surface. It is constantly being released into the air by burning fuel, by many kinds of factories, by the breathing of living things, and by the decay of various substances. It is estimated that during each hour about two and one-half tons of carbon dioxide are breathed into the air by each million human beings. When we consider the innumerable[1] other living things which breathe out carbon dioxide, and that these would soon die if they could not get rid of it, it is evident that its production is continual and large.

Experiment 5. How may carbon dioxide be prepared? Will it burn? Will wood burn in it? Put a tablespoonful of baking soda into a drinking glass. Pour a little vinegar or lemon juice on the soda. The bubbles which immediately form are carbon dioxide gas, which remains in the bottom of the glass. When the bubbling stops, thrust a burning match into the glass. Does carbon dioxide burn? Does it allow the wood to burn in it?

*Oxygen is inhaled during the life processes of plants and animals. The ways of taking in oxygen vary in different living things, but in all living things oxygen combines in every part of the organism[1] with other substances. This oxidation gives the organism its energy. By means of this energy the organism does its work, whatever it may be — whether growth, heartbeat, running, or thinking. One of the substances resulting from the oxidation and release of energy is carbon dioxide. If this carbon dioxide becomes present in too large quantities, it is injurious[2] to the organisms that produce it. In large cities the amount of carbon dioxide may sometimes become five times as much as in the open country, and in poorly ventilated (see page 175) schoolrooms the amount may even exceed ten times that found in the open country. The carbon dioxide is not a poison, as has sometimes been claimed, and the excessive amount seems injurious chiefly in ways not fully known rather than by any directly harmful effects. Good ventilation helps to remove excess carbon dioxide, to bring in fresh supplies of oxygen, and to keep the air in motion. Green plants consume carbon dioxide in their processes of making food, and return oxygen to the air (Chapter XXI).

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[1] *Innumerable* (in nu′mer a bl): too many to be counted.

23. ***Nitrogen not an active substance.** Although nitrogen composes almost four fifths of the volume of the air, it is not usually regarded as so important as oxygen and carbon dioxide. As a gas it enters our bodies and in the process of breathing passes out again without being changed. Possibly the percentages of both oxygen and carbon dioxide in the air would be too great for use by living organisms if it were not for the presence of nitrogen. Thus nitrogen may be said to dilute[3] the oxygen and

---

[1] *Organism* (or′gan izm): an animal or a plant.

[2] *Injurious* (in ju′ri us): causing injury or harm.

[3] *Dilute* (di lute′): to make a strong substance weaker by adding another substance to it; thus, strong coffee is diluted, or made weaker, by adding water to it.

carbon dioxide in the air. But it is supremely important, however, because it is essential in the construction of many food substances necessary to both plants and animals.

24. *Water vapor in the air. There is always some water vapor in the air. Sometimes the amount is more than the air will carry, and then the vapor forms fog or clouds (Fig. 21) and may even fall as rain, snow, sleet, or hail.

FIG. 21. WATER IN THE AIR

In this picture large amounts of water are in the air in the form of clouds. (Photograph by Gayle Pickwell, taken in New York)

Almost all objects upon the earth's surface contain some water. All living things require water. It is the means of circulation[1] and lubrication[2] within all living things. Water is constantly being added to the air from all these objects by evaporation. The water passes into the air as vapor. The amount of water carried into the air by any single acre of growing plants during a season is surprising to most people. For example, an average of fifteen tons of water is carried into the air during the production of one bushel of ripened corn. A corn crop of fifty bushels to the acre would then have carried into the air an average of seven hundred fifty tons of water per acre during the growing season.

---

[1] *Circulation* (sur ku la′shun): the process by which a gas or a liquid flows to all parts of a body. *Circulate* (sur′ku late): to move by a curving path back to the starting point.

[2] *Lubrication* (lu bri ka′shun): using fluids, such as oil, to lessen friction.

25. †Dust and air. Air is probably never entirely free from dust except when especially treated in laboratories. Various kinds of materials, such as rock, soil, and clothing, are constantly being reduced to dust. Some of this is fine enough to be carried by the air even when only slight air movements occur. Some can be carried only when strong winds are blowing. Volcanic[1] dust (Fig. 22) sent into the air is sometimes so fine that it is estimated that it may remain in the air and even circulate several times round the earth before falling.

Some of the dust which has been found as high as two miles above the earth is living. When such dust alights in favorable places, it grows into small plants, as will be explained in Chapter XXIII. Thus the air may be said to carry both living and dead dust. There is commonly not much danger to human health from the dust of the air.

26. †Chemical and physical changes. Oxidation is an illustration of chemical change in substances. In the case of the oxidation of iron, for example, oxygen unites with iron to form iron oxide.[2] Carbon and oxygen may unite in the proportion of two parts of oxygen to one of carbon to form carbon dioxide. Similarly, hydrogen and oxygen may be united in the proportion of two parts of hydrogen to one of oxygen to form hydrogen oxide, which is water.

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[1] *Volcanic* (vol kan′ik): from a volcano (see Fig. 22).

[2] *Oxide* (ox′ide): a substance chemically combined with oxygen; as, carbon dioxide or water.

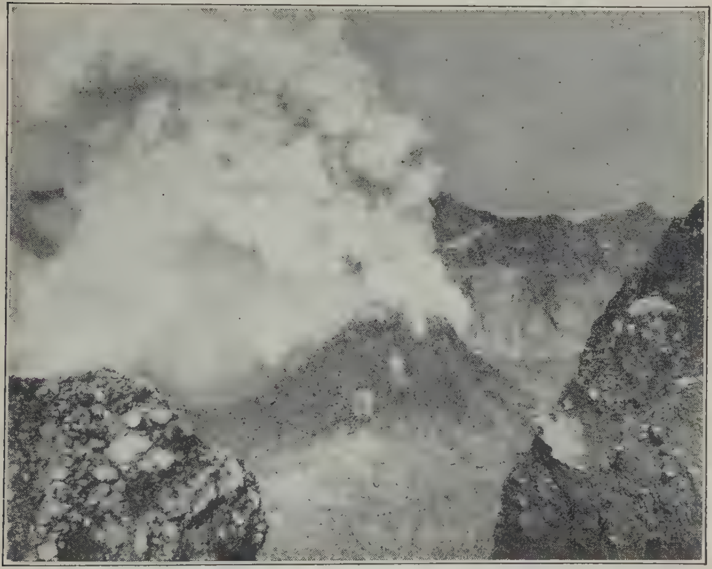

FIG. 22. MT. VESUVIUS IN ACTION

This volcano, through several openings, has been sending smoke and dust into the air for many centuries. (Photograph by Publishers Photo Service)

†Iron oxide may be rubbed into a fine powder and a change thus be made in its physical appearance. Its chemical nature would not be changed, however, unless either its oxygen and iron were separated from each other or other substances were united with the iron and oxygen which compose the iron oxide. Water may be in liquid form, as usually seen, it may be frozen into snow, sleet,

or ice, or it may be heated until it becomes water vapor or steam. The change from ice to liquid or to water vapor are physical changes produced by temperature changes. They are not *chemical* changes, since water as a solid, a liquid, or a gas is still hydrogen oxide; that is, the hydrogen and oxygen remain united in the chemical relation of two parts of hydrogen to one of oxygen. But when potassium chlorate was heated (see page 42), the change in temperature did produce a chemical change. The potassium chlorate was broken up into two new substances, one of which was oxygen. In similar manner, when a current of electricity is passed through a tube

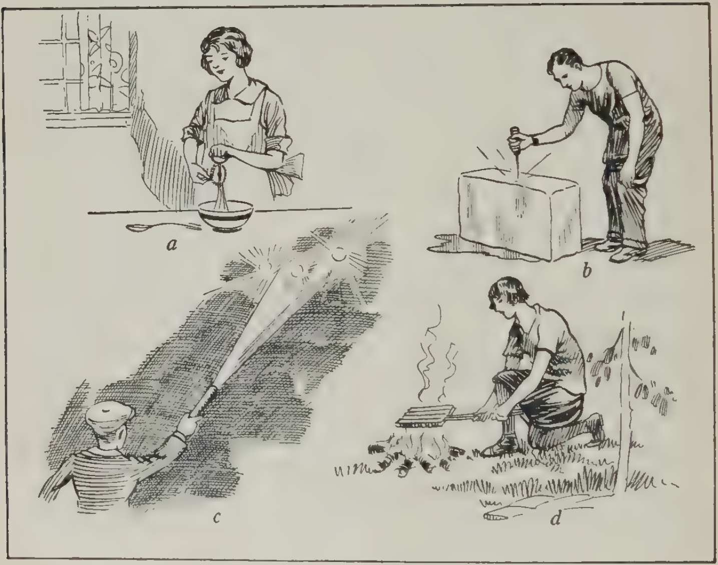

FIG. 23. PHYSICAL AND CHEMICAL CHANGES

What physical changes are illustrated in *a* and *b*, and what chemical changes are illustrated in *c* and *d*?

of water the chemical union of the hydrogen and oxygen is broken. The hydrogen oxide (water) no longer exists, but in its place are two separate gases, hydrogen and oxygen. In fact, this chemical change in water is a common way of securing free hydrogen and oxygen for laboratory experiments.

27. ***Elements, compounds, and mixtures.** Oxygen, hydrogen, carbon, and iron are known as elements; they are simple substances two or more of which may combine to form compounds. About ninety elements are known. Chemical change occurs whenever substances unite or break up to form new substances. Compounds result from chemical change. Physical change has to do with changes in form, or from one of the three states of matter — solid, liquid, and gaseous (Fig. 23).

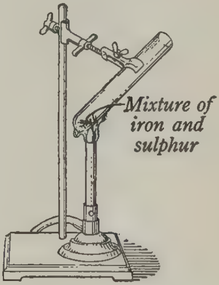

FIG. 24. MAKING IRON AND SULPHUR COMBINE

Experiment 6. Can we produce both physical and chemical changes with iron and sulphur? Make a small lump of sulphur into a fine powder. Have you produced a physical change in the sulphur or a chemical change? Add to the sulphur about half as much iron filings as the amount of sulphur. Mix the iron and sulphur thoroughly. Hold a magnet [1] near enough to the mixture to attract the iron filings. Does removing the iron with the magnet produce a physical change in the mixture or a chemical change? Again mix the iron and sulphur. Heat the mixture in a test tube (Fig. 24). When the contents of the tube begin to glow brightly, remove the burner and allow the contents to cool. Break the test tube and examine its contents. Can you see anything now which looks like either the iron or the sulphur? Does the magnet attract any of the material now? Have the iron and the sulphur been changed? Did the heat produce a physical change in the iron and sulphur or a chemical change?

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[1] *Magnet* (mag′net): a piece of iron, steel, or other metal which attracts iron or steel. It possesses *magnetism* (mag′net ism) and is *magnetic* (mag net′ik).

> What chemical and physical changes are taking place in Fig. 20, p. 43 (blasting)? What physical changes are taking place in Fig. 13, p. 31 (potato gun)? Tell which of the following are physical changes and which are chemical changes: (1) dissolving sugar in hot coffee; (2) freezing ice cream; (3) making carbon dioxide (Experiment 5, p. 45); (4) rusting iron; (5) decaying animal and vegetable matter; (6) making a partial vacuum; (7) making candy; (8) slicing meat.

28. *Mixtures of solids, liquids, and gases. If a pint each of the grains of wheat and corn are poured together and thoroughly stirred, we have a mixture of wheat and corn. The structure of the individual grains will not have been changed, and we can separate all of them again. Similarly, if some lubricating oil is poured into a glass of water the oil remains on top of the water. If these liquids are stirred, the oil may for a time form a mixture with the water, but usually the mixture soon separates into oil and water. If some ether is poured carefully into a glass cylinder already partly filled with water, the liquids mix with one another very slightly, but slowly. If vinegar is added to water, however, the two liquids mix very readily. When solids such as sugar or salt are dissolved in water, the solid is mixed throughout the liquid, and what is known as a solution results. When sugar is put into lemonade, the lemonade becomes sweet all through. When salt is put into soup, all the soup tastes of the salt. Some liquids may be readily made into mixtures, as when a salt solution and a sugar solution are poured together. The form, appearance, and state′ of the salt and sugar are changed, but not their composition. It is true, however, that chemical changes often occur readily between certain substances in solution when these same substances not in solution would combine slowly or not at all.

†When the two pints of grain were stirred together, the mixture amounted to almost or quite a quart. If the wheat fitted into the spaces between the corn grains, possibly less than a quart resulted. This would be the case with the use of large grains of corn and small grains of wheat. When gases are mixed together they act very differently from solids and from most liquids. A gas always tends to expand throughout the space which contains it. If a pint bottle of cooking gas is released in a schoolroom, the gas spreads throughout the whole room, and if a pint of another kind of gas is released in the same schoolroom, it too spreads throughout the whole room. A number of different gases might thus be mixed together, each gas filling the whole room. Each gas of the mixture would still exist with its structure unchanged, though we should have difficulty in separating the gases.

Experiment 7. Will alcohol and water occupy less space after they are mixed than before they are mixed? Fill a test tube half full of water. *Very carefully* fill the tube with alcohol, taking care to pour the alcohol down the side of the test tube. Put your thumb over the full tube and shake the tube violently. What happens? Does it seem as if the alcohol and water had acted in a way that reminds you of the wheat grains finding places between the corn grains? Explain.

29. *Structure of compounds. We have already discussed the elements carbon, hydrogen, oxygen, and iron, and have learned that these unite to form such chemical compounds as water, carbon dioxide, and iron oxide. Much more complex[1] compounds are sometimes formed when a large number of elements have united. Many different elements may unite to form one compound.

It is only by means of chemical changes that we can separate the substances composing a compound. We can separate the substances composing a mixture by physical changes such as are produced by evaporation or freezing.

Physics and chemistry are the special sciences which deal more fully with the nature and structure of matter.

30. †Analysis and synthesis. When a substance is studied to find out what chemical elements or compounds it is made of, the substance is said to be *analyzed*, and the process is called *analysis*. When a compound is built up by combining elements and compounds, the substance is said to be *synthesized*, and the process is called *synthesis*.

TESTS AND GUIDES FOR STUDY AND REVIEW

Some of the following statements are true; can you pick these out? Some are false; can you make these true by changing not more than *two* words? Some contain blanks; can you fill these so as to make correct statements? There is also a new kind of statement with five possible answers. Can you select the best answer?

1. About ---- per cent of the air is oxygen and ---- per cent is nitrogen.
2. Burning is rapid oxidation.

---

[1] *Complex* (kom′pleks): the opposite of simple; made up of many parts.

3. A fire would cease to burn if all the air were removed from around it.
4. The breathing of animals adds to the great quantities of air
   nitrogen oxygen carbon dioxide dust argon.
5. A substance which is a necessary part of many foods is
   nitrogen argon water vapor dust carbon dioxide.
6. Tearing one's clothes is an example of a chemical change.
7. Burning one's clothes is an example of a chemical change.
8. A simple substance, every part of which is exactly like every other part, is called an ____.
9. When two or more elements combine to form a new substance every portion of which is exactly like every other portion, the new substance formed is called a ____.
10. If sugar and sand were stirred together, the result would be a compound.

SCIENTIFIC PUZZLES AND GAMES

1. Can you solve the following problem? Mr. Smith is building a new fence all the way round his place. The lot is fifty feet across the front, but is much higher at one end than at the other. It is one hundred feet deep from front to back. Mr. Smith plans to use pickets across the front and narrow boards along the sides and back. As the house is green, trimmed with white, he plans to paint the fence to match. How many feet of fencing will he have round his place?

Which of the scientific attitudes (see pages 8–10) did you use in solving this problem?

2. Suppose, as you are going home from school tonight, you were to see a man rush out of a yard carrying a small child in his arms. The child is screaming loudly as the man jumps with her into an automobile and speeds down the street, turning at the first corner. What should you do? Justify your answer by quoting one of the scientific attitudes.

UNIT III. WATER AND MAN'S USES OF IT

CHAPTER V

WATER AND ITS WORK

Some Questions this Chapter Answers

Are there places on the earth where there is no water? Of what is water made? What kinds of substances will dissolve in water? How and why is water distilled? What is meant by "boiling"? How does water do work? What are surface water and ground water? What causes an artesian well? Where and how are dams built? How are water wheels used? How is a siphon used? Can water be compressed like air? How may water be used in machines for pressing cotton into bales, crushing rock, and similar purposes?

31. †Water everywhere on the earth. We often hear the expression "as dry as the Sahara Desert." This idea is common because many people think of the Sahara Desert as the driest area which can be imagined. Many people think it is a place where there is *no* water except in an occasional spot. There is no region on the earth where there is no water. Even in the parts of the driest desert where there are no pools of water, water nevertheless exists. It is in the air in the form of vapor. It exists in very small quantities within what seems to be the driest sand. Some water exists chemically combined in the rocks and minerals.

Experiment 8. Does dry soil contain water? Weigh a panful of the driest soil you can find. Heat it for an hour or so, but not hot enough to burn up any bits of wood or other similar matter which might be in the soil. Weigh it again. Did it lose weight as a result of the heating? Did the soil contain water before it was heated? Do you think it possible that after the heating it may still contain some water? Can you suggest a further experiment by which you might find out?

32. †The structure of water. If a gallon of the element oxygen and two gallons of the element hydrogen were put together into a vessel, the two gases would form a *mixture.* The gases would soon distribute themselves equally throughout the vessel without uniting chemically. If a flame or a spark were introduced into the mixture of hydrogen and oxygen, an extremely violent explosion would occur and water would be formed. The explosion would indicate that a chemical change had taken place, giving off much energy, and that a chemical compound had been formed. The oxygen and hydrogen would unite to form molecules of water, which is different from either hydrogen or oxygen. Two volumes of hydrogen unite with one volume of oxygen to form water.

Experiment 9. Can it be shown that the elements oxygen and hydrogen unite to form water? Thrust a thick piece of *cold, dry* metal into the flame of a gas burner (Fig. 25). After an instant remove the metal. Can you observe steam rising from its surface? Explain, keeping in mind the facts that cooking gas contains hydrogen and that the air round it contains oxygen.

33. Water carries substances in solution. More substances dissolve in water than in any other solvent.[1] There are substances, however, which practically do not dissolve in water at all, though they may dissolve in other solvents. Thus, grease spots can be removed from clothing with carbon tetrachloride but not with water, because the grease dissolves readily in carbon tetrachloride but not in water.

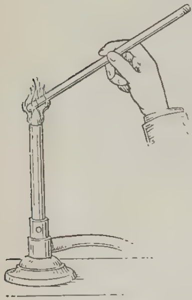

FIG. 25. WATER IS FORMED DURING BURNING

How many other substances can you name which do not dissolve readily in water?

Ocean water is a solution in water of salt and small quantities of many other substances. Water that is strictly pure is never found in streams or lakes. More or less mineral matter is always found dissolved in such water. In certain springs the water contains so much dissolved mineral matter that some of this matter is deposited in odd and beautiful shapes and colors (Fig. 26).

In many parts of the world there are "mineral springs." These contain sufficient quantities of dissolved minerals to give the water a pronounced taste or smell, or both. The water from such springs is commonly thought to be especially healthful to drink, and even to be a cure for rheumatism, kidney disease, and other diseases. There is much evidence, however, which seems to indicate that there is little or no foundation for such a belief, and that mineral waters in general are probably no more healthful to drink and no more able to cure diseases than ordinary water.

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[1] *Solvent* (sol′vent): a substance in which another substance dissolves.

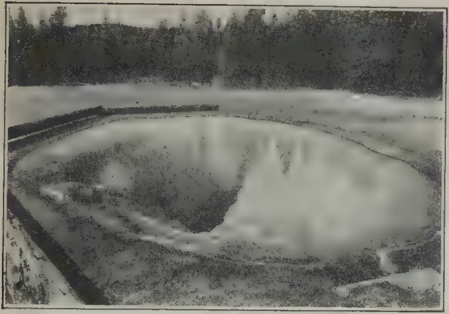

FIG. 26. MORNING GLORY POOL, YELLOWSTONE NATIONAL PARK

The water contains dissolved mineral matter, some of which has been deposited in beautiful colors upon the sides and bottom of the pool

34. *Distilled water is pure water. *Experiment 10.* How can water be distilled? Put some soil, a little ink, and some salt into a flask partly full of water. Arrange the apparatus as in Fig. 27. Allow the water in the flask to boil for some time. Has the distilled water in the test tube any color or any taste? Evaporate a little of the distilled water in a clean dish. Is any solid substance left behind in the dish when the water is all evaporated? Answer the question asked at the beginning of this experiment by filling each of the blanks in the following sentence with either the word "condensing"[1] or the word "evaporating": Water is distilled by ---- it and then by ---- the vapor.

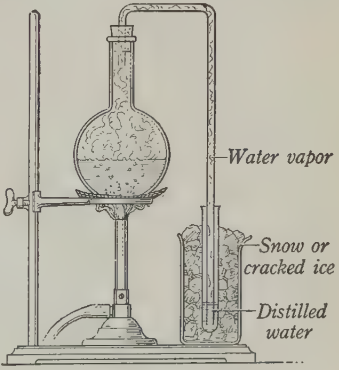

FIG. 27. DISTILLING WATER

Why is distilled water used by druggists and physicians in their work? Why is it used in automobile batteries?

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[1] *Condense* (kon dens′): to change from a vapor or a gas to a liquid or a solid.

35. †Boiling is merely rapid evaporation. We are apt to think that only water in the liquid state evaporates, but ice also evaporates to some extent. Water vapor is invisible; nobody ever saw steam. One often hears people speak of seeing the steam from a locomotive whistle or from a teakettle spout. What they see is not the steam itself but the tiny drops of liquid (water) formed when vapor (steam) has been sufficiently cooled by the cold air so that it condenses. You can prove the truth of this last statement by observing a teakettle in which water is boiling. You will see nothing *immediately* in front of the spout, but you will see a cloud of *condensed* vapor, like fog, an inch or so from the end of the spout. An explanation of this fact is that steam consists of individual water particles, called molecules, which are too small to be seen. When enough of them have been condensed into a drop, however, the drop is easily seen.

How is it possible for clothes to freeze dry in winter?

36. †How does water boil? When water is heated, bubbles appear at once upon the bottom and sides of the vessel. These first bubbles are air which was dissolved in the water when the water was colder but which cannot remain dissolved when the water is heated. Some of the water is evaporating all the time; that is, some molecules of water are escaping from the surface all the time. The hotter the water becomes, the faster it evaporates; that is, the more molecules escape from the surface. Finally the water reaches its boiling point, 100° C. The molecules now escape not only from the surface but also from within the water, forming bubbles of steam. These steam bubbles are forced to the surface, because steam is lighter, volume for volume, than water. The water is now boiling.

37. *Running water does important work. Whenever it rains, the water flows from higher ground to lower ground. Thus it runs off the hillsides into the valleys, thence down the valleys, forming streams flowing always downward toward the ocean. Wherever the valley widens and the current becomes sufficiently slow, the stream spreads out and forms a *lake.*

*As the streams flow downward to the ocean, the running water does important work in moving soil and rocks from the hills into the valleys and to the ocean. Men use the running water to do important work, such as transporting boats and rafts to places downstream and turning water wheels which run mills and generate[1] electric current.

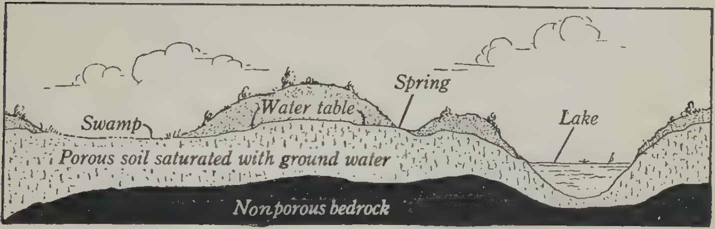

FIG. 28. SPRINGS, SWAMPS, AND LAKES ARE FORMED WHERE THE WATER TABLE IS NEAR THE SURFACE

38. Ground water. Water runs downhill on the surface of the ground in streams, but it also sinks into the ground, forming ground water. Ground water sinks readily through layers, or *strata,* of porous materials, such as sand and gravel, until it reaches bedrock. It then collects above the nonporous bedrock, forming a saturated[1] layer of soil

---

[1] *Generate* (jen′er ate): to produce or cause to be made.

[2] *Saturate* (sat′u rate): Anything is saturated with a substance when it holds within itself as much of the substance as possible. Thus, a sponge is easily saturated with water.

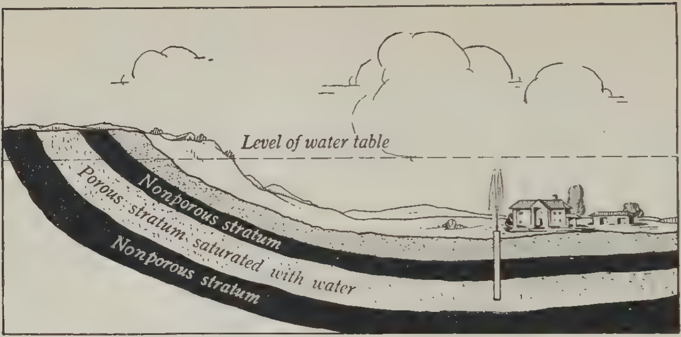

Fig. 29. An Artesian Well is Possible only where there are Sloping Strata

which is as full of water as it can be (Fig. 28). The top of this saturated layer is called the *water table.* During the rainy season the water table is nearer the surface of the ground than in the dry season.

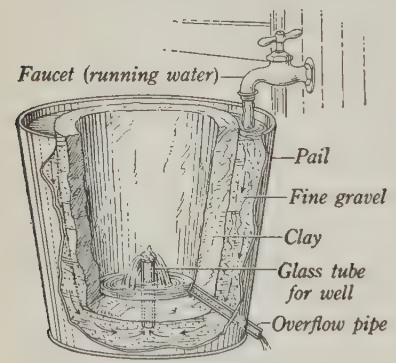

Fig. 30. Diagram of a Model of an Artesian Well

The ground water flows downward along the surface of the bedrock. If the water table reaches the surface on a slope farther down the mountain, a *spring* results (Fig. 28); if it barely reaches the surface over a considerable area, a *swamp* is formed; if it reaches well above the ground over a considerable area, a *lake* is formed.

39. *Artesian wells. In some mountainous regions there are places where porous layers, or strata, of gravel or rock are found between nonporous[1] strata of rock. These strata may all be folded so that in some places the porous *stratum*, or layer, is exposed to the rainfall (Fig. 28). The water is then prevented from escaping to the surface and may be imprisoned beneath the valley floor miles away. If a well is bored through the nonporous stratum of rock (see Fig. 29) above this imprisoned water, the water spouts out, sometimes to a considerable height, forming an artesian well.

> Why does the water spout out of an artesian well instead of flowing out quietly, as from a spring? It is said that along some portions of the Atlantic coast it would be possible to construct artesian wells by boring into the ocean bottom some distance offshore. Can you make a diagram similar to Fig. 29 showing how the strata might be arranged so as to make such a condition possible?
>
> ***Project.*** To make a model of an artesian well. Fig. 30 shows how a model of an artesian well was constructed in an old metal pail. The overflow tube has nothing to do with the well, but was put in to remove the water as it flowed from the well into the "valley." What in Fig. 29 corresponds with the clay stratum in the model? with the fine-gravel stratum? with the metal sides of the pail?

40. *Dams. Along the streams in the mountainous regions of the United States and Canada are hundreds of waterfalls. These are capable of being developed into enormous sources of energy usually called water power (see frontispiece[2]). Dams are often constructed at the lower ends of valleys to raise the level of the water and thus increase its stored energy. They are also built at the ends of river valleys to form artificial lakes in which to collect and store vast quantities of water for water supply and irrigation[1] (Fig. 31). The dam is usually constructed of concrete reënforced[2] by means of steel bars, which run through the concrete, thereby greatly increasing its strength. The dam is made much wider at the bottom than at the top. With its weight thus mostly at the bottom, it can withstand much greater pressures than if its walls were of the same thickness throughout. Why?

---

[1] *Non, in, un* or *dis* at the beginning of a word means "not" or "the opposite." *Nonporous* means "not porous."

[2] *Frontispiece* (frun'tis piece): an illustration placed in the beginning of a book.

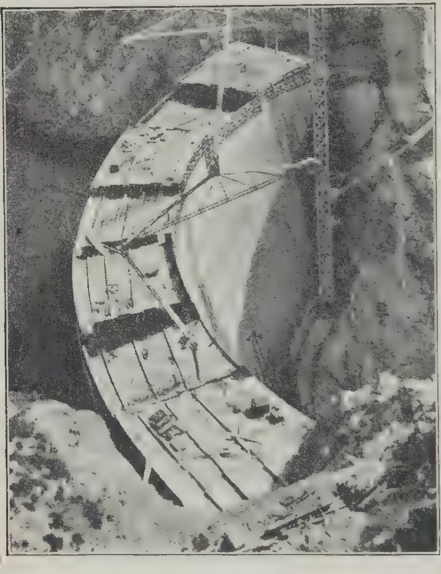

FIG. 31. BUILDING A MODERN DAM ACROSS A MOUNTAIN VALLEY

If you have tried to dam the water of a small stream, you can imagine the great strength needed to dam the water of a great river

Water pressure, unlike air pressure, increases uniformly as the depth of the water increases. The pressure of water 34 feet below the surface is the same as the air pressure at sea level — about 15 pounds per square inch. At twice 34 or 68 feet below the surface the water pressure is twice 15 pounds per square inch, or 30 pounds per square inch, at three times 34 feet it is 45 pounds per square inch, and so on. Fig. 14, p. 33, will help you to understand these statements, though you must keep in mind the fact that the total pressure at the bottom of the caisson is the water pressure plus the air pressure, because the air is pressing down upon the water surface.

---

[1] *Irrigation* (ir ri ga′shun): watering land by artificial means for agricultural purposes.

[2] *Reënforce* (re en fors′): to make stronger; to add strength to.

The pressure below the surface of the water depends only upon the depth of the water and not at all upon how much water there happens to be. Thus the water pressure against the wall of a dam thirty-four feet below the water surface is fifteen pounds per square inch, no matter whether the lake extends a hundred feet behind the dam or a mile; and the pressure at any point, both in water or in air, pushes with the same force in every direction.

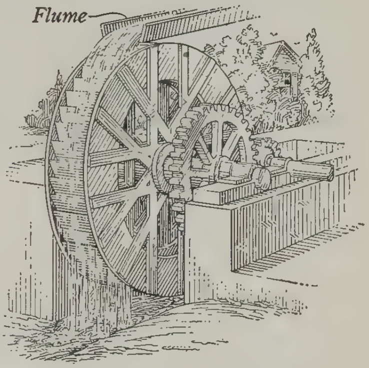

FIG. 32. THE OVERSHOT TYPE OF WATER WHEEL

Compare the ways in which this wheel and those shown in Figs. 33, 34, and 39 operate

Why do the foundations of dams need to be on bedrock?

41. *Water wheels. Common types of water wheels are the overshot wheel (Fig. 32) and the undershot wheel (Fig. 33). The overshot wheel is common in mountainous regions, where the beds of the streams slope steeply but where the streams do not carry a great volume of water. This type of wheel is turned chiefly by the weight of the water on the blades as the water falls. The overshot wheel cannot be used in flat countries; the undershot wheel can, where there is a great volume of water but little fall. This wheel is turned by the pressure of the water as it flows against the blades.

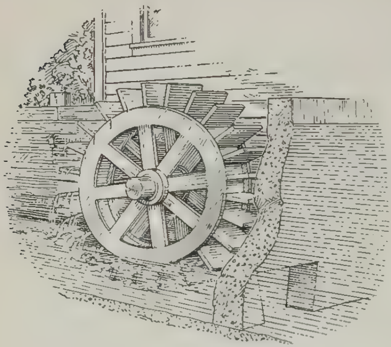

FIG. 33. THE UNDERSHOT TYPE OF WATER WHEEL

*The Pelton wheel (Fig. 34) is a special form of undershot wheel. It finds wide use for small-power purposes in cities large enough to have waterworks.

*The water wheel which is most widely used and which makes the best use of the flowing water is the turbine (Fig. 35). The water flowing through the pipe is directed against the curving blades of a horizontal[1] wheel which is completely under water. Some of the largest turbines in the world, capable of developing 70,000 horse power each, are used to generate

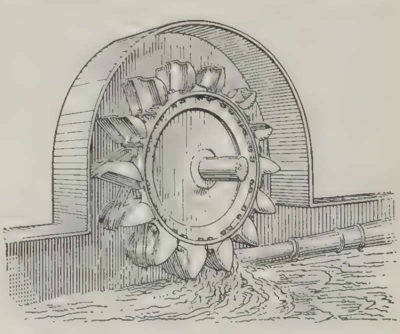

FIG. 34. THE PELTON WATER WHEEL

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[1] *Horizontal* (hor i zon′tal): level, like the horizon.

electrical energy at Niagara Falls. One plant alone is capable of developing 450,000 horse power.

Project. To construct of thin boards, such as shingles or cigar boxes, water wheels with which to demonstrate overshot, undershot, and Pelton water wheels.

Special Report. What industries are located at Niagara Falls? What is the available water power in the United States and Canada?

42. *The siphon is operated by air pressure. If a tube is entirely filled with water and is placed with the ends in two vessels containing water (Fig. 36), the water will flow through the tube out of the vessel in which the surface of the water is the higher. A tube used in this way is called a *siphon*.

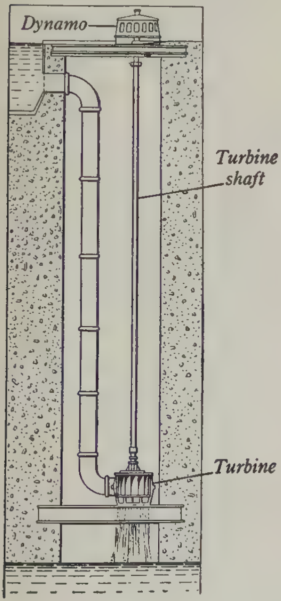

FIG. 35. THE TURBINE

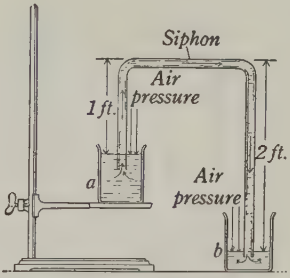

FIG. 36. THE SIPHON

Would the siphon flow in a vacuum? Explain your answer

We learned in Chapters II and III that at sea level the air pressure is great enough to hold up a column of mercury about 30 inches high or a column of water about 34 feet high. If no air is allowed to enter the siphon tube, the air pressure at sea level would be able to hold up a column of water about 34 feet high in each side of the siphon, from the water surface to the bend. In Fig. 36 the air pressure on the surface of the liquids in both vessels is the same, but the air pressure is holding up a longer column in vessel *b* than in vessel *a*. Thus less of the air pressure on the surface of the water in *a* is being used to hold up the column of water than is the case of the air pressure on the surface of water in *b*. That is, if the column above *a* is 1 foot high, the air pressure on the surface of *a* could hold up a column about 33 feet higher than it is supporting. Similarly, if column *b* is 2 feet high, the air pressure on the surface of the water in *b* could still lift water only about 32 feet higher than it is supporting. The remaining, or unused, air pressure is therefore greater on the surface of *a* than it is on the surface of *b*. Hence the remaining air pressure in *a* forces the water over into *b*

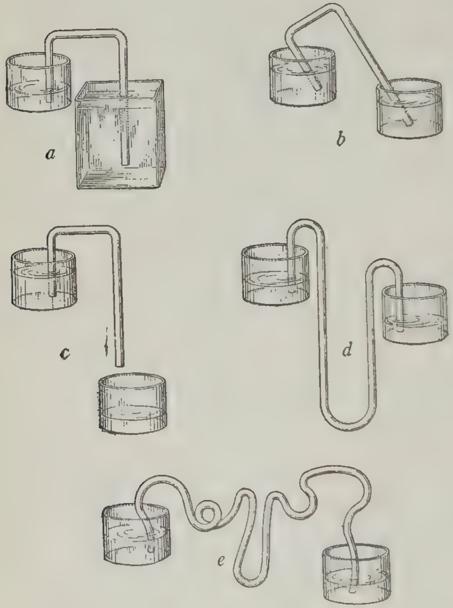

FIG. 37. TYPES OF SIPHONS

Which of these siphons will operate in the positions shown in the diagrams?

in spite of the fact that the remaining air pressure in *b* tends to push the water back into *a*. In actual practice the air pressure cannot lift water higher in a siphon than in a lift pump — that is, not more than from 20 to 28 feet — because of the friction of water in the tube.

Experiment 11. Can water be siphoned from a vessel containing a little water into another vessel containing much more water (Fig. 37, *a*)? Try this. Can water be siphoned from one vessel to another when the siphon is slanting (Fig. 37, *b*)? Try this. Can water be siphoned from one vessel to another when the lower end of the siphon is not under water (Fig. 37, *c*)? Try this. Can water be siphoned from one vessel to another when the upper end of the siphon is not under water? Try this. Can water be siphoned from one vessel to another when the bend of the siphon is below the level of water in both vessels (Fig. 37, *d*)? Can water be siphoned through a tube with many turns? Bend a glass tube in some such shape as that in Fig. 37, *e*; then find the answer to this question. Summarize in a sentence each of the facts which you have learned from these experiments.

43. Water cannot be compressed. Some football players can kick a football sixty yards. This is possible because the air in the football is instantly compressed when the kicker's toe strikes the ball. Thus the compressed air pushes against the toe, forcing the football away toward the goal. If the football were filled with water, however, it could not be kicked more than a few feet, not only because water is heavier, volume for volume, than air but chiefly because water cannot be compressed like air. Scientists have learned to make many useful applications of the fact that water cannot be compressed, just as they have learned to make use of the fact that air can be compressed.

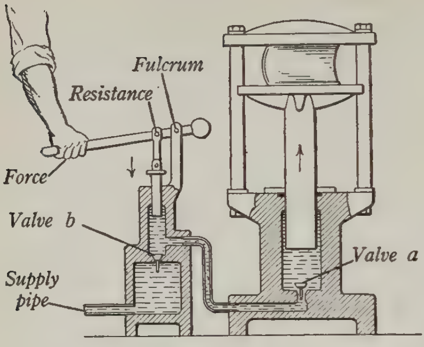

FIG. 38. THE HYDRAULIC PRESS

Would air serve as well as water or oil in the hydraulic press? Explain

If pressure is applied to water or oil which is confined within a vessel so that it is not able to escape, the pressure is transmitted[1] through the water or oil in every direction without loss. Thus, if you filled a bottle entirely full of water, stopped it with a cork, of which the end against the water was one square inch in area, and then were to strike the cork a fifteen-pound blow, the result would be the same as if you had struck a fifteen-pound blow against every square inch of the inside of the bottle. The water would transmit the force without loss to every square inch of the inclosing bottle.

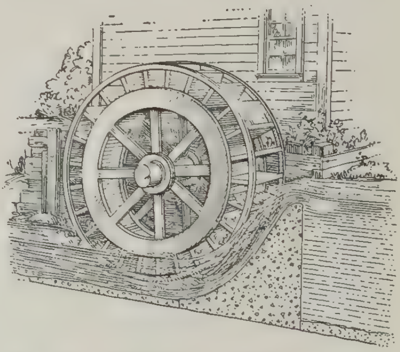

FIG. 39. THE BREAST-SHOT TYPE OF WATER WHEEL

Why is the breast-shot wheel better than the undershot wheel (Fig. 33, p. 66) in places where the water can be dammed up only a few feet?

44. *Action of the hydraulic press. The hydraulic press (Fig. 38) is a practical application of the facts just explained. The action of the piston and the valves is very similar to that of the force pump. When the small piston is pulled upward, valve *a* is forced shut by the weight of the large piston pressing on the water above it. Valve *b* is forced open by the pressure of the water from the supply pipe. When the small piston is pushed downward, valve *b* is forced shut and *a* is forced open. The water transmits the force from the small piston to the large piston without loss. Thus if the small piston has an area of one square inch, and the big piston an area of twenty-five square inches, the force exerted[1] upward against the big piston will be twenty-five times as great as the force exerted downward by the small piston, because the big piston is twenty-five times as large as the small one.

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[1] *Transmit* (trans mit′): to send through or across.

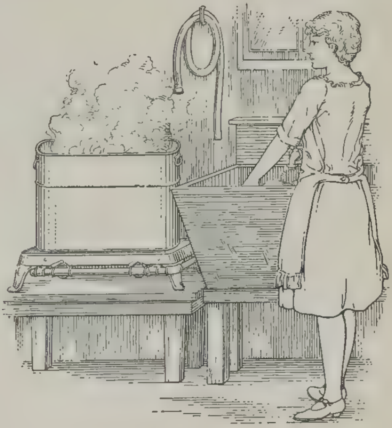

FIG. 40. A HOUSEHOLD PROBLEM

Without pouring or dipping water from the boiler, how can it be emptied?

Hydraulic presses are used for compressing paper and cotton bales, for raising and lowering dentists' and barbers' chairs, for pressing oil out of seeds, for punching holes in iron plates, and for various other purposes. Hydraulic presses have been constructed with which a force of twenty million pounds can be exerted. They are widely used in modern industries.

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[1] *Exert* (eg zurt'): to put forth or make an effort.

SCIENTIFIC PUZZLES AND GAMES

1. In Fig. 39, p. 70, and in the legend below the figure a problem is presented. See if you can solve it.

2. Do the same for the wash boiler, Fig. 40, p. 71.

TESTS AND GUIDES FOR STUDY AND REVIEW

Some of the following statements are true and some are false. Pick out the true ones and correct the false ones by changing not more than two words. Fill the blanks wherever you find them in other statements, and in the statements containing five possible endings choose the one which is best.

1. Some impurities can be removed from water by distilling it.
2. Much of the soil which is now in valleys was formerly on hills and mountains.
3. The water which pours out of artesian wells fell as rain in the **mountains** **valleys** **rivers** **ocean** **lakes.**
4. Dams are usually built across the upper ends of valleys.
5. Dams are built wider at the bottom than at the top in order to withstand better the pressure of the air against them.
6. The type of water wheel most frequently found in mountains is the ____ water wheel.
7. The type of water wheel which makes the best use of the flowing water is **the overshot** **the breast-shot** **the Pelton** **the turbine** **the undershot.**
8. A siphon in a vacuum would work **not at all** **to some extent** **as well as it would with ordinary air pressure** **slightly better than with ordinary air pressure** **much better than with ordinary air pressure.**
9. In a deep mine the air pressure would probably force water less than twenty-eight feet in a siphon tube.

CHAPTER VI

SECURING A WATER SUPPLY

Some Questions this Chapter Answers

How can water be regarded as a luxury as well as a necessity? What is pure drinking water? How may pure water become impure? Are spring water and well water always pure? What are the best sources of rural water supply? of city water supply? Why is it necessary for the water supply of great cities to be under public control? How do large cities secure sufficient quantities of water for all their needs?

45. Water a luxury and a necessity. We are so accustomed to having all the water we want for every purpose by simply turning a faucet or by going to the well or pump that it is difficult for us to imagine life in homes which are not sufficiently supplied with water. In colonial times one well which was located in the middle of the village supplied all the people. This method is still in use in villages of some foreign countries. In Nazareth, for example, some of the wells of Bible times (Fig. 41) are still visited daily by women who carry from them supplies of water in earthen jars. In some of the largest cities of China wells provide the water, and it is carried by those who are to use it or is distributed in wheelbarrow water wagons from house to house.

Should we be likely to use as much water as we do if all that we used for various household purposes had to be carried from a distance (Fig. 42)?

46. *The water supply must be pure. "Pure" in this sense does not mean absolutely free from all substances except water; the water must not contain anything unwholesome. Matter which is not alive, such as mud, sand, and dissolved minerals, may give the water an unpleasant color or taste without making it unfit to drink. Living matter, such as bacteria[1] and other living things, however, is always present in natural waters to some extent. These may not impart color, odor, or taste in any way, and yet if certain kinds are present they may render the water

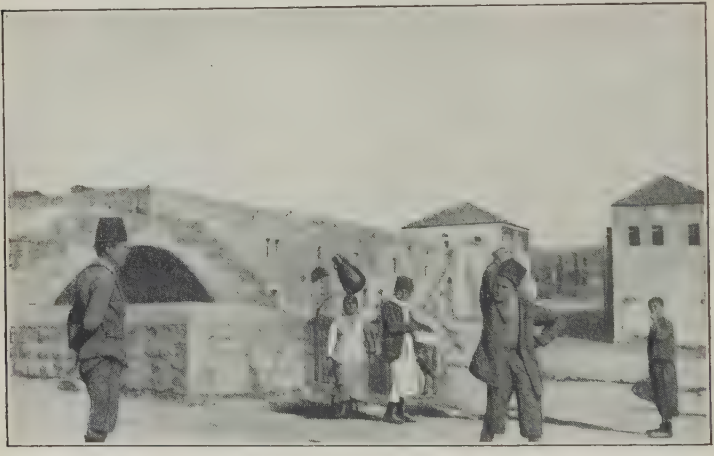

FIG. 41. AT MARY'S WELL, IN NAZARETH, PALESTINE

The water flows in the shaded area behind the wall. It is carried away in jars upon the backs of men or upon the heads of women entirely unfit for drinking and for household uses. Human and animal wastes are liable [1] to contain the kinds of germs [2] which, if allowed to get into water, make it dangerous to drink. It is necessary, therefore, to make sure that the water supply is not contaminated [3] by animal and human wastes.

---

[1] *Bacteria* (bak te′ri a): a certain group of very small plants. Some of the germs which cause diseases are bacteria.

47. *Danger from surface drainage.[4] People in the country usually depend for their water supply upon wells, springs, or streams. But although these sources of water supply may be abundant and may be conveniently located for all purposes, there is always grave danger that they may have become polluted [5] by surface drainage (Fig. 43). Even very deep wells, the water of which is usually pure, may become contaminated if they are not so constructed as to prevent surface water from draining into them (Fig. 44). Moreover, it is not always true, as many

FIG. 42. THE VILLAGE PUMP

In earlier days all the water used was pumped from a well in the middle of the village

---

[1] *Liable* (li'a bl): likely in the sense that something undesired or dangerous may occur.

[2] *Germs* (jurms): a name for small plants and animals which may produce diseases.

[3] *Contaminate* (kon tam'i nate): to make dangerously unclean.

[4] *Drainage* (drain' aj): the flowing of water from higher to lower levels; also the liquids which drain.

[5] *Pollute* (po lute'): to contaminate by adding unclean or dangerous material, that is, *pollution* (po lu' shun) means *contamination* (kon tam'i na'shun).

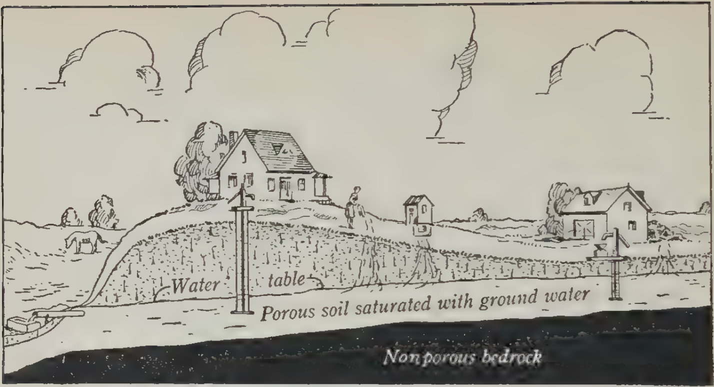

FIG. 43. DIAGRAM SHOWING HOW WATER MAY BECOME POLLUTED
What are the sources of pollution of drinking water in this picture?

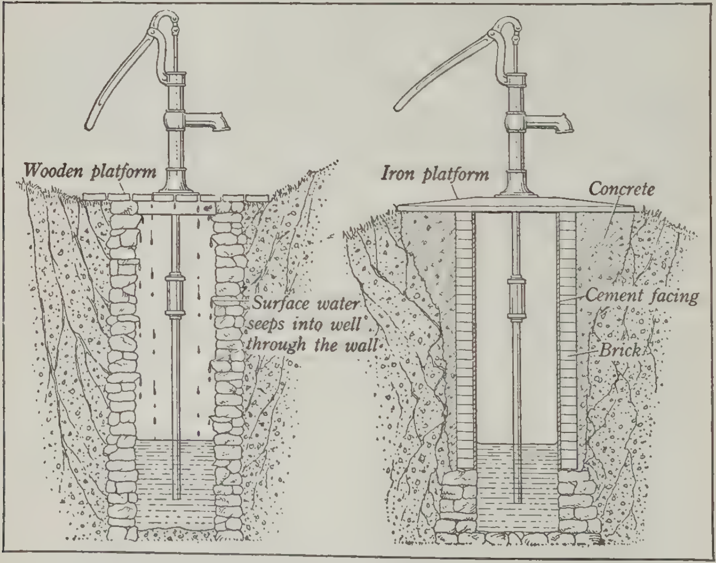

FIG. 44. RIGHT AND WRONG WAYS TO BUILD A WELL
What are the advantages in construction of the well and protection of the water?

people believe, that streams always purify[1] themselves by running a few miles.

*Surface drainage, such as is shown in Fig. 43, may carry to human beings typhoid fever, intestinal[2] diseases, and parasites[3] such as the hookworm and the tapeworm. It may carry to farm animals hog cholera, anthrax, and intestinal parasites.

The only way in which rural[4] dwellers can find out whether their water supply is pure is by having a sample of the water analyzed to see whether it contains dangerous germs. The state university, the state board of health, or the public health bureau in the nearest large city will usually make such an analysis, sometimes free of charge. If the source of water is located where it is liable to be contaminated, it should be analyzed at least twice during a summer.

*While people are on their vacations they sometimes contract typhoid fever and other serious diseases by drinking water which has become polluted with sewage.[5] Visitors to camps or resorts should take great care to make certain that the water supply has been recently tested for purity and has been pronounced wholesome by the state board of health or other similar agency. In some states the Boy Scouts have done the very valuable public service of sending samples of water from streams and wells along the highways to the state boards of health for analysis. They have then put up signs on each source of water stating whether the board has pronounced the water safe to drink. If the source of water is an open well, a spring, or a stream, however, one cannot always be sure that the water is "safe" even though it bears a "safe" sign, for the water may have become contaminated since the analysis was made. Boards of health sometimes recommend that people on outing trips make sure that their drinking water is safe by boiling it for twenty minutes or by putting into it a small amount of chloride of lime. Chloride of lime tablets, usually sold as "chlorine tablets," can be bought at any drug store.

---

[1] *Purify* (pu′ri fi): to make pure.

[2] *Intestinal* (in tes′ti nal): having to do with the bowels, or *intestines*.

[3] *Parasite* (pair′a site): a living plant or animal which lives on, inside, or at the expense of another plant or animal.

[4] *Rural* (ru′ral): having to do with the country as different from the city.

[5] *Sewage* (su′ij): the waste matter which flows from homes and streets through pipes called *sewers* (su′ers).

48. Running water easily secured in rural homes. In past times country dwellers were satisfied with their water supply if they had a lift pump or a well near the kitchen door; today an increasing number of progressive[1] farmers and ranchers are securing the same conveniences of running hot and cold water that are found in modern city homes.

*Before water can be made to flow from faucets (Fig. 59, p. 102) on the top floor of the house, however, the water in the pipes must have considerable pressure. In rural homes this pressure may be produced conveniently in three ways: (1) by damming a mountain spring to form a reservoir[2] high enough above the house so that the water will flow to the top floor; (2) by constructing a tank which holds a sufficient supply of water at a level above the highest faucet in the house, to insure a similar flow; (3) by installing a compressed-air water system with which the water may be forced to the top of the house by compressed air.

---

[1] *Progressive* (pro gres'iv): eager to make progress; using the latest scientific devices or knowledge.

[2] *Reservoir* (rez'er vwor): a place in which water is collected and stored.

*A force pump (see page 37) is commonly used to lift water into a tank located outside the house or on the roof or in the attic. The pump may be operated by a small gas engine, or the wind may be used to turn a windmill (Fig. 45) which is so constructed that it moves the piston of the force pump up and down.

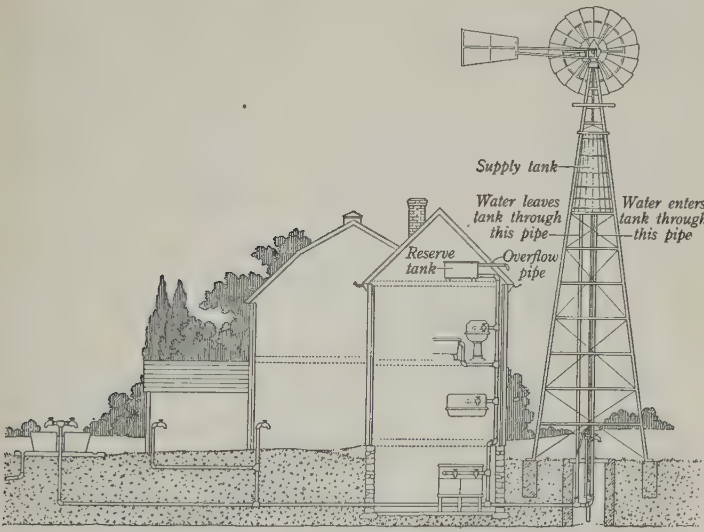
Supply tank
Water leaves tank through this pipe
Water enters tank through this pipe
Reserve tank
Overflow pipe

FIG. 45. MAKING AIR PUMP WATER

When the wind fails the hand pump may be used. A device in the pump enables the water to be pumped directly into the supply tank, into the reserve tank, or to the barn. Why is the supply tank higher than the house?

What are the advantages and disadvantages in the three locations of the tank named in the preceding paragraph?

Special Report. How does a hydraulic ram lift water from a running stream into a reservoir above the stream?

*Fig. 46 shows the construction of a compressed-air water system. Water is forced by a force pump into the tank. As the water level rises in the tank, the air confined above the water is crowded into a smaller space. Hence its pressure is increased, just as in the dome of the force pump. The pressure gauge indicates when sufficient pressure has been produced in the tank to force water through the pipes to the upper floors. The force pump is then stopped. When a faucet is opened in any part of the house, the compressed air in the tank forces water to flow out of the faucet. As the water in the tank is used, however, the air pressure in the tank becomes less, because the air expands to take the place of the water which is pushed out of the tank; consequently more water has to be pumped into the tank for two reasons: (1) to maintain a sufficient air

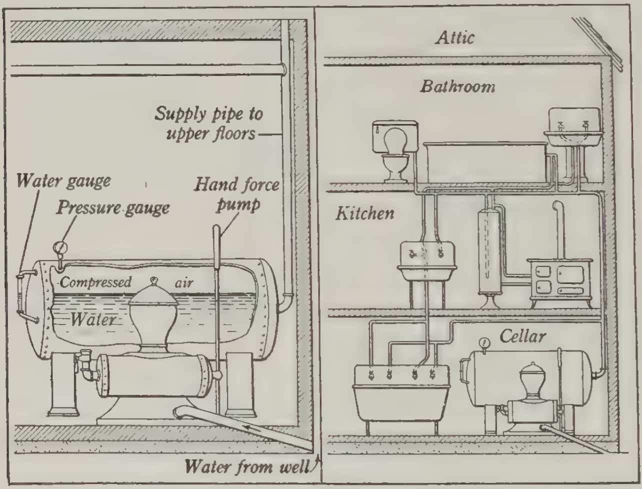

FIG. 46. A COMPRESSED-AIR WATER SYSTEM

What uses of compressed air are shown in this picture?

pressure and (2) to provide an abundant supply of water for all household purposes.

49. †The city water supply under public control. Small cities sometimes can secure from wells or springs all the water they need. Usually such sources do not furnish sufficient quantities for drinking, fire-fighting, disposing of sewage, sprinkling lawns and streets, and all other purposes. An ample supply can usually be secured from a lake or river close by or, in some cases, from a mountain lake or stream many miles distant from the city. Cleveland and Buffalo, for example, secure their water from Lake Erie (Fig. 47), and Chicago from Lake Michigan. St. Louis obtains its water from the Mississippi River. Los Angeles and New York were able to secure a sufficient quantity of pure water only by bringing it from the distant mountains. These cities have found it necessary to be continually searching for new sources of water supply to provide for growth of population.

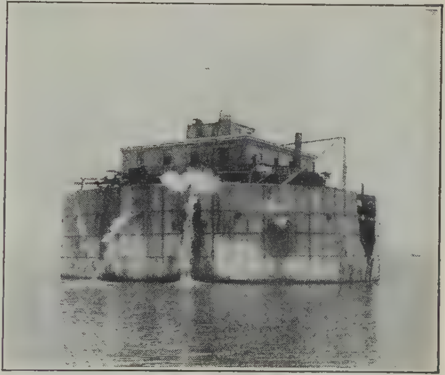

FIG. 47. ONE OF CLEVELAND'S WATER-PUMPING STATIONS ON LAKE ERIE

By taking water several miles from shore a pure water supply may be had. (Photograph by Ewing Galloway)

Some years ago Los Angeles purchased a tract of land in the Sierra Nevada Mountains, where a great artificial lake was made by damming the Owens River. This source of water, over two hundred miles from the city, furnished enough water to supply two million people. The growth of the city soon made it necessary to seek new sources of water in order to keep up with the growth of population. Los Angeles is now building a water-supply system to be completed about 1934, which will be one of the greatest in the world. It will cost $175,000,000 and will furnish water for ten million people. The water will be brought from the Colorado River, a distance of two hundred sixty miles — more than a hundred miles farther than the distance which New York City brings its water from the Catskill Mountains. The water will be led from the river into a reservoir twenty miles long, where solid particles will settle. It will then enter a great pipe eighteen feet in diameter and made of steel and reënforced concrete. The water will be pumped through this huge main over mountains hundreds of feet higher than the source and through fifty-five miles of tunnels, one of these tunnels being twenty-six miles long. Many reservoirs are built along the way to keep the supply even. With this system Los Angeles will put to useful purposes water which is now wasted and even does great harm by floods. The building of this system is one of the greatest engineering feats since the building of the Panama Canal.

Special Report. Find out where and how New York City secures its water supply. Describe the advantages, disadvantages, and methods used in the water supply in your home or in the town or city in which you live. How is it kept or made pure?

50. *How is the water supply purified in towns and cities? After the water is brought to the city it must usually be treated to make certain that it is wholesome. Water obtained from rivers and lakes, especially, is liable to be more or less contaminated. Many cities use one or more of the following methods of purifying their water supply: (1) spraying the water into the air so that the harmful impurities[1] can be exposed to the sunlight and to the oxygen in the air and thus made harmless (Fig. 48),

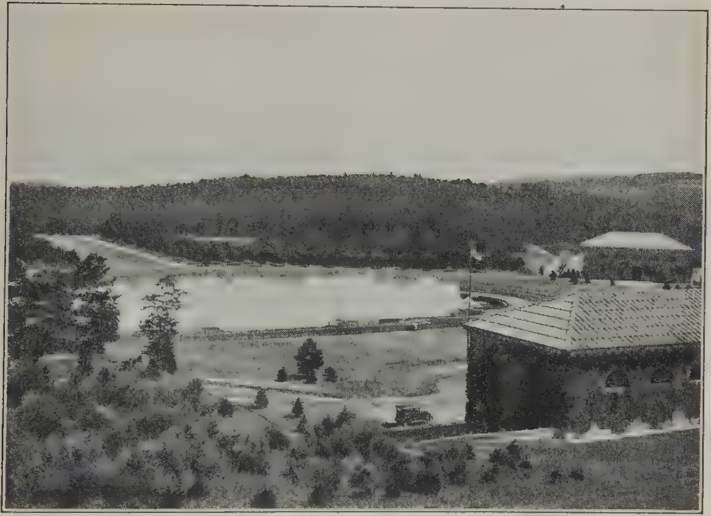

FIG. 48. PART OF NEW YORK CITY'S WATER SUPPLY

After the water is thus sprayed into the air to expose it to sunlight and oxygen, it is piped to the city more than a hundred miles away

(2) filtering it to remove the solid impurities, (3) storing it in reservoirs until the solid impurities settle out, or (4) treating it chemically to kill the germs.

Experiment 12. Can solid impurities be removed from water by filtering it through sand? Place a one-hole stopper in the end of a long glass tube at least an inch in diameter (Fig. 49). Fill the tube with sand. Pour water which is slightly muddy into the top of the tube until it begins to drip into the glass. Is the water clear? Answer with a complete sentence the question asked at the beginning of this experiment.

---

[1] *Impurity* (im pu'ri ty): that which is not pure, or which contaminates.

†The method of filtering water through sand and gravel, to free it from solid impurities such as sediment[1] and germs illustrated in Experiment 12, is used in many cities (Fig. 50). Practically all the germs can be removed in this way, provided the filtering beds are deep enough and are properly cleaned.

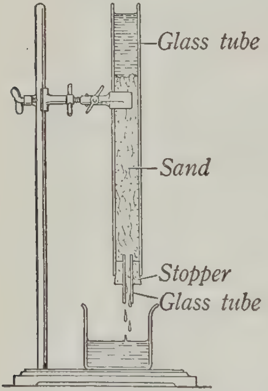

FIG. 49. FILTERING WATER THROUGH SAND

†The storage[2] method of freeing water from solid impurities consists of allowing the water to remain for several weeks or months in great settling basins, or reservoirs. The solid particles settle very slowly; but if a small quantity of alum is added to the water, a sticky substance is formed to which the solid particles cling. The larger particles thus formed settle more rapidly. These reservoirs must be cleaned regularly.

Various types of household filters are intended to remove germs from drinking water. One type consists of a small strainer which screws over the end of the faucet; another consists of a metal tube surrounding porous stone, brick, or other porous materials. It is probable, however, that none of these filters wholly frees the water from germs even though the filters are frequently cleaned, for many kinds of germs are small enough to pass through the pores[1] of the filter with the water. Moreover, if such filters are not frequently cleaned, the water that has passed through may be found to contain even more germs than the water directly from the faucet, because harmful germs may multiply in the solid material which collects in the pores of the filter. It is not certain that any faucet filter yet invented makes polluted water sufficiently pure for drinking.

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[1] *Sediment* (sed′i ment): solid or undissolved particles in water or other liquid.

[2] *Storage* (stor′aj): the act of storing something or the space in which something is stored.

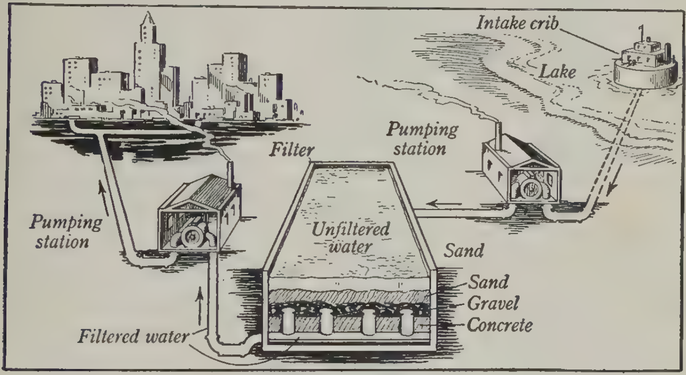

FIG. 50. HOW SOME CITIES PURIFY THEIR WATER

†When water is purified chemically the germs are not removed but are killed. Usually liquid-chlorine gas is added to the water in very small quantities, which are sufficient to kill the germs but not to injure human beings. Millions of gallons of water are thus purified daily in city water systems. Sometimes compounds of chlorine are used instead of liquid chlorine.

In every large city the water is tested daily for purity.

---

[1] *Pore*: a very small opening or hole; as, the pores of the skin.

There are always some bacteria in the water supply. It is not necessary that drinking water should be entirely free from bacteria, since the body is able to overcome germs when these are not too numerous, and not many kinds of germs are harmful. Whenever the daily tests show a marked increase in the number of germs in the water or show germs of a dangerous nature, the health authorities at once take whatever steps are necessary to restore the water to the necessary degree of purity.

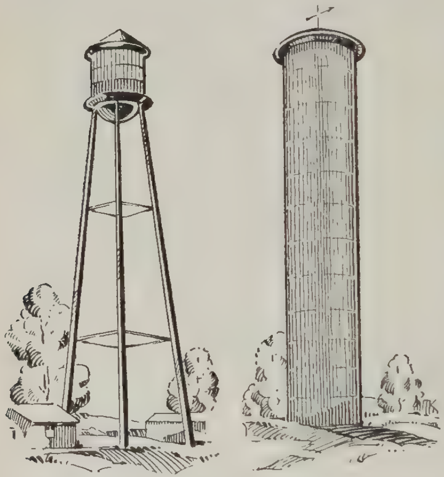

FIG. 51. A STANDPIPE AND A TANK FOR STORING WATER

51. Distribution of water often difficult. After the water has been purified, it is distributed through mains to all parts of the city. Wherever it is possible the water is stored in great reservoirs built in the highest parts of the city, so that the water will flow through the mains and to the tops of the buildings. In small cities, however, where the water is secured from a river or a lake the surface of which is below parts of the city, stores of water are commonly pumped into tanks or standpipes (Fig. 51). In large cities, when necessary, the water is forced through the mains by powerful force pumps. In some cities, however, these pumps cannot force water to the tops of the tall buildings. They cannot supply sufficient water at all times even for ordinary purposes and especially not for extra demands, such as fires. In such cities water is commonly pumped from the mains by smaller force pumps to tanks on the roofs of the tall buildings. These tanks supply the upper floors and provide a means of fighting fires.

The higher the level of water in the standpipe or reservoir, the greater the pressure in the mains. Explain. The pressure in the faucets becomes less the higher they are in a building. Explain. The farther away the faucets are from the reservoir or standpipe or pumping station, the less the pressure. Explain.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. It is always dangerous to drink water containing bacteria.
2. Water may be wholesome to drink even though it contains some dissolved minerals.
3. Water from deep wells is less liable to become contaminated than surface water.
4. A dangerous disease known to be contracted sometimes from drinking water is **hydrophobia** **rheumatism** **paralysis** **typhoid fever** **cancer**.
5. Water may be made safe for drinking by adding to it a small amount of **salt** **chloride of lime** **plaster of Paris** **carbon dioxide** **soda**.
6. Water can be forced from the basement to the top of a house by means of ____ air.
7. Harmful germs in water are killed by oxygen and sunlight.
8. Filtering water through sand and gravel removes **none** **a few** **many** **nearly all** **all** of the harmful germs.
9. Water will flow from faucets in the house provided the faucets are lower than the reservoir or tank in which the water is stored.

CHAPTER VII

KEEPING CLEAN WITH WATER

Some Questions this Chapter Answers

How does soap help to get rid of dirt? Why are clothes rinsed after being washed? How does hard water differ from soft water? How do soap, borax, and other substances help in softening water? How does a water-softening device operate? How does a washing machine operate? What are the best ways for keeping clothing clean and neat? How should sewage be disposed of in the country? in the city? What is the relation between proper plumbing and good sanitation?

52. Water and soap. Have you ever thought about how difficult it would be to keep clean without water? Imagine the condition of our bodies, our homes, and our cities without water and the knowledge of how to use it to keep ourselves and our environment clean and sanitary.[1] Such knowledge, however, has only been recently gained and is by no means general in all parts of the world.

Pliny, a great Roman scientist and writer who lived in the first century A.D.,[2] states that soap was invented by the Gauls. His writings do not say that they used it for washing or cleaning but only to give a bright color to the hair. It was probably introduced by the Germans into Rome, where it was used both as a medicine and as a cleansing agent.

---

[1] *Sanitary* (san′i ta ry): having to do with producing healthful conditions.

[2] *A. D.:* the first letters of "Anno Domini," which means in the year of [our] Lord, or since the birth of Christ. *B. C.*: the first letters of "Before Christ"; that is, before the birth of Christ.

In pioneer times, when every family had either to make its own soap or go without, soft soap was made by first boiling hardwood ashes to extract the substance called lye, straining the lye water, and then boiling it with fats such as lard and tallow (Fig. 52).

*Hard soaps are made today by boiling animal fats or vegetable oils with a lye commonly known as sodium hydroxide. Salt is added at the proper time in the boiling, causing the soap to rise to the top. The soap thus separates from the other substances which are produced in the kettle at the same time (Fig. 53).

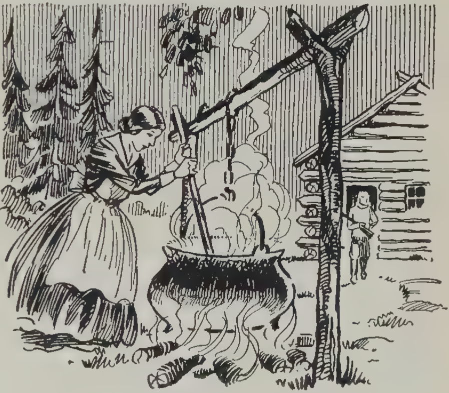

FIG. 52. MAKING SOAP IN PIONEER DAYS

53. *Washing and rinsing. The skin of the human body is usually moist and oily. Fine particles of dirt may adhere to the skin. Some of this dirt, along with dirt from other sources, may be absorbed[1] by our clothing. Water dissolves some solid particles and carries away dirt which is loosened from the clothes and body by rubbing, but water alone will not remove the oily materials. When soap is added to the water the oil is broken up into very fine particles which float in the soapy water and can be removed by rinsing.[1]

---

[1] *Absorb* (ab sorb′): to take in a liquid or other substance, as a blotter takes in ink.

Why is hot water a better cleanser than cold water?

54. *Hard water and soft water. When water has dissolved out of the rocks and soils certain of the compounds of the metals calcium and magnesium, it is called *hard water*. Water without these compounds in solution is called *soft water*.

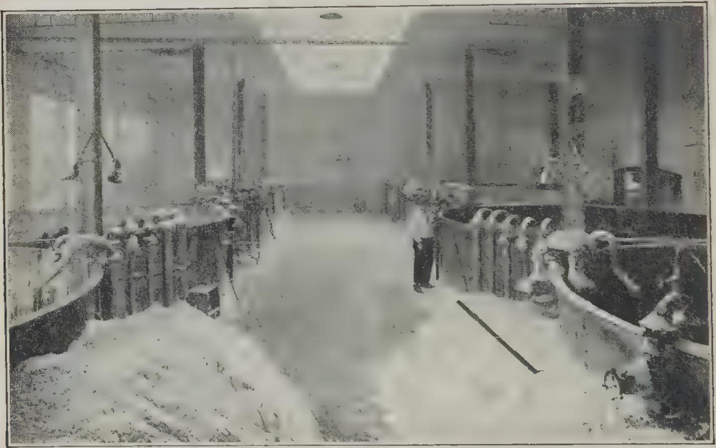

FIG. 53. MODERN SOAP-MAKING

In these large kettles thousands of pounds of soap are made at a time

*Soap dissolves readily in soft water. When soap is put into hard water it combines with the calcium and magnesium compounds to form a coating on the surface of the water. No soap bubbles will form until soap has first combined with all the calcium and magnesium compounds in the water. This is the reason why hard water is not satisfactory for laundry purposes, though it is wholesome for drinking. In parts of the country where the water supply is hard, rain water, which has no minerals in solution, is collected in rain barrels or in cisterns for washing and cleaning. Various substances are added to hard water to combine with the calcium and magnesium compounds and thus leave the soap free to attack the oils and dirt. Borax and ammonia are especially good for laundering[1] and for softening bath water, but they are expensive for general laundry uses. Washing soda is excellent for softening hard water.

---

[1] *Rinse*: to wash lightly without rubbing.

*Many washing powders which contain borax and washing soda are effective for softening water. Some of these will attack the clothing, especially woolens, if the powders are poured directly upon the clothing without first being dissolved in water; therefore it is safer to dissolve the powder in the water before putting the clothes into the tub.

The coating which soap makes with hard water can be removed from the bathtub by using a cloth upon which a little turpentine or kerosene has been poured.

> ***Special Reports.*** Find out what you can about the composition and values of hard-water soaps and of scouring powders.

Some kinds of hard water when heated leave a white solid, chiefly lime, on the bottom and sides of the vessel. The heating coils in water heaters and furnaces sometimes become so filled with lime that they no longer heat the water effectively[2] and have to be replaced.

55. A device for softening water. In some cities (for example, Columbus, Ohio) where the water supply is very hard, the water is softened before it is sent into the pipes. Where this practice is not followed, the hard water can be satisfactorily softened for all household purposes by the use of water-softeners, one type of which is shown in Fig. 54. The hard water from the supply pipe (often called the main) is admitted to the bottom of the softener and rises first through fine gravel and coarse sand, then through a softening compound of sodium, silicon, aluminum, and oxygen. The calcium and magnesium compounds in the hard water combine with the substances composing this layer. The softened water then passes out at the top of the tank to various parts of the house. After two or three weeks of use, depending upon how hard the water is and how much of it is used, the deposits of calcium and magnesium have to be removed from the softening compound. Salt solution is poured into the top of the softener. The salt combines with the calcium and magnesium compounds and makes the soften-

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[1] *Launder* (lon′der): to wash and iron clothes.

[2] *Effectively* (e fek′tiv ly): securing the results expected or desired.

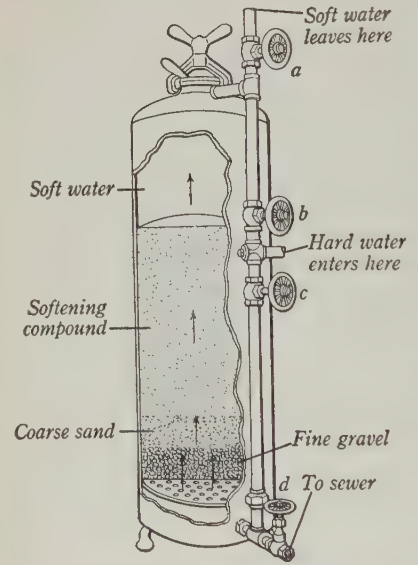

FIG. 54. A WATER-SOFTENER

Valves *a* and *c* are open while valves *b* and *d* are closed. Hard water then enters at the bottom and is so treated that soft water flows out of the top. Can you explain which valves are open and which are closed when the softener is being flushed?

ing compound as it was at first. The restoring solution is then drained into the sewer. Enough fresh water is allowed to pass through the softener to remove all traces of the restoring solution. After this the softener is again ready for use and as capable of softening water as at first.

56. *Machines in the home laundry. In some parts of the world clothes are washed in running streams. The wet clothes are spread flat upon rocks or boards and are beaten with paddles to loosen the dirt. In early times dirt in the clothes was usually loosened by rubbing the wet clothes upon a board or upon a large stone. The board is still much used for washing. But there is no longer necessity for doing this heavy work by hand. Washing machines of many types launder the clothes more quickly and quite as well. Fig. 55 shows one type of electric washer. Soiled clothes are put into the tub with water and soap. A small electric motor, by one or another of several different methods, depending upon the type of washer, causes the water to pass rapidly through and about the clothes, removing the dirt. Some types of washer do not have a wringer, but accomplish the same purpose by whirling the clean wet clothes round in a cylinder, thus throwing the water out of the clothes into the tub as they whirl.

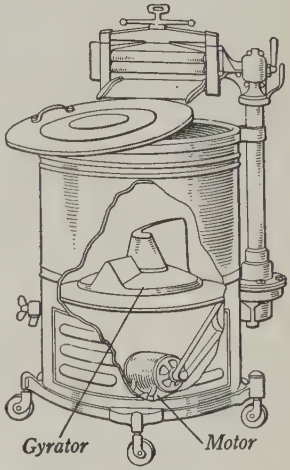

FIG. 55. DIAGRAM OF AN ELECTRIC WASHING MACHINE

Describe the way in which this machine operates

Mangles, or ironing machines, are finding a place in many modern homes. With these machines the clothes are pressed between rolls of metal heated either by gas or by electricity. A small electric motor turns the rolls.

57. Removing stains from clothing. People are judged in part by their personal appearance. This statement does not mean that it is necessary to wear expensive clothes or to have several different suits or dresses: it means that one's clothing should be neat; that is, free from holes, carefully pressed and brushed, and free from stains.

*It is not possible to state in a few sentences how to remove all stains from clothing, because (1) there are many different kinds of stains, and (2) substances which produce stains act in different ways upon different cloth materials and dyes.

*Stains should be attacked as soon as possible, since old stains are harder to remove than fresh ones. Never use strong chemicals to remove stains. If the chemical substance is strong enough to remove the stain quickly, it may also be strong enough to make holes in the cloth. Always work on only a small area of the cloth at a time. Remove the stain from that area before you go farther, even though you may be working on only a small part of one stain. Always begin at the edge of a stain and work toward the middle.

*The commonest stains are probably those made by food and oily substances, ink, and paint. Stains on goods that can be washed can usually be removed by using warm water and soap, meanwhile rubbing the spot thoroughly. Such spots on goods that cannot be washed can usually be removed by sponging the spot with carbon tetrachloride while holding a soft folded towel under the spot to absorb the oil and other materials as fast as the carbon tetrachloride removes them. Carbon tetrachloride is better than gasoline or benzine for cleaning clothes in the home, because it will not explode or burn.

†Indelible ink cannot be successfully removed from cloth. Printer's ink and India ink may often be removed by sponging the spot with carbon tetrachloride. Stains made by writing ink can often be removed by applying first ammonia and then oxalic acid, repeating if necessary, then by washing all these chemicals out of the cloth when the spot is removed. In using oxalic acid and ammonia to remove stains it is always well to try the effect of these chemicals first upon another piece of the same cloth to see whether it injures the cloth or changes its color. This is especially necessary in the case of silk clothing. Do not use household ammonia, but get 10 per cent ammonium hydroxide solution from your druggist. The oxalic acid solution is a saturated solution made by dissolving in pure water all the oxalic acid crystals that the water will dissolve. Oxalic acid is a poison and should be kept out of the reach of children.

†Paint stains may usually be removed with carbon tetrachloride. If the stain is an old one, moisten the spot thoroughly with carbon tetrachloride, then roll the cloth up with the stain inside. The carbon tetrachloride is thus prevented from evaporating so quickly and therefore continues to act upon the spot.

Special Reports. Explain how rust stains, iodine stains, grass stains, and other kinds of stains may be removed from clothing. (Consult *Farmers' Bulletin No. 861*, United States Department of Agriculture.)

58. †Dry cleaning and pressing. In the modern process of dry cleaning the clothes are thoroughly washed in large washing machines of the same plan as those used in the home. The liquid used in these machines is usually gasoline, benzine, or a similar liquid obtained from gasoline. Garments such as white trousers are washed in soap and water instead of in the cleaning liquid. When the clothes have been in the washing machine a sufficient length of time, they are put into a large cylinder. This whirls rapidly, removing most of the cleaning liquid, in the same way that some types of washing machines dry the clothes. The clothes are then put into a metal chamber, in which the temperature is between 250° and 300° F. Here the high temperature kills all the germs. The clothes are next placed in a drying room, through which pass currents of warm air. After the clothes are dry, spots which have not been removed by the cleaning liquid are removed by hand. The clothes are now ready to be pressed. Women's garments are practically all ironed by hand with electric irons. Men's garments are pressed on pressing machines. These are of several types: one presses the trousers, another the shoulders of the coats, and another the sleeves, and so on. The part to be pressed is placed upon a pad connected with a vacuum pump. Another pad, heated with steam, is pressed lightly on the garment. The air pressure forces the steam from the upper pad through the garment into the partial vacuum in the second pad. After the clothes are pressed they are hung up in a warm room and left until they are thoroughly dry.

59. *Sewage disposal[1] in the country. The problem of sewage disposal is of great importance. It is closely connected with the problem of water supply. The country dweller no longer has a good excuse for having an old-fashioned open outside toilet. The country home which is not supplied with running water can be equipped with an indoor chemical closet (Fig. 56) at very small cost. The body wastes are received in the large pail partly filled with water containing a small quantity of antiseptic[1] solution. This antiseptic solution kills the germs and prevents unpleasant odors. About every ten days the contents of the pail are emptied into a barrel from which the bottom has been removed and which has been buried in the ground. The wastes, which have been changed almost entirely to liquid form, sink into the ground and do no harm.

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[1] *Disposal* (dis po'zal): the act of getting rid of.

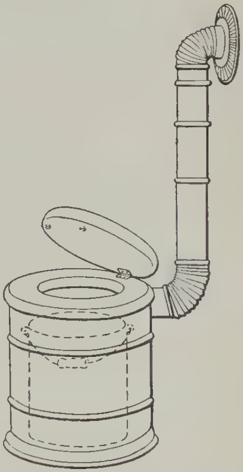

Fig. 56. A Chemical Toilet for Homes which do not have Running Water

*Another sanitary substitute for the old-fashioned open toilet is the dry-earth toilet. An outside toilet is constructed in the ordinary way, except that the vault is made of concrete instead of being merely a hole in the ground. Whenever the toilet is used, the wastes are sprinkled with a small amount of chloride of lime to kill the germs and then are covered with dry dust or sand. Thus the wastes are made harmless[2] and odorless.[2] The vault can be emptied of its dry contents without difficulty.

The chemical toilet and the dry-earth toilet are recommended by boards of health not only for use in country homes but also for churches, country schools and hotels, and camps and pleasure resorts.

---

[1] *Antiseptic* (an ti sep'tik): germ-killing.

[2] *Less* at the end of a word means "without" or "unable to do." Thus *harmless* means "unable to do harm" and *odorless* means "without odor."

*Where the country home is supplied with running water, the septic[1] tank offers the most satisfactory means of disposing of the sewage in a sanitary way (Fig. 57). The sewage enters the first compartment, where it is attacked by certain kinds of bacteria. These bacteria feed on the wastes, killing the harmful germs in them and changing the wastes to a liquid form. The liquid overflows from this compartment into a second one, where the purifying process is continued. The liquid which is finally distributed into the soil from the second compartment is almost clear. The soil bacteria complete the destruction of any particles of solid material which may remain, rendering the wastes entirely harmless.

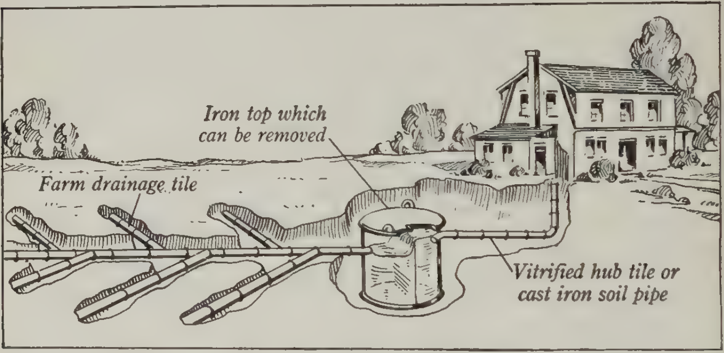
Iron top which can be removed
Farm drainage tile
Vitrified hub tile or cast iron soil pipe

FIG. 57. A SEPTIC TANK FOR USE IN HOMES WHICH HAVE RUNNING WATER BUT WHICH ARE NOT CONNECTED WITH SEWAGE SYSTEMS

Septic tanks are commonly constructed of concrete, but especially constructed metal septic tanks (Fig. 57) can be bought which need only to be buried in the earth.

---

[1] *Septic* (sep′tik): producing decay through the action of certain kinds of bacteria.

The septic tank should be connected only with the toilet. The kitchen sink and the bathtub and laundry tubs should have a separate drain. No disinfectant,[1] such as lye or strong acids, should ever be poured into a toilet which drains into a septic tank, because the disinfectant would kill the germs which purify the sewage.

60. *Sewage disposal in cities. Cities by the ocean commonly pipe their sewage a long distance from shore. The sewage is broken up and made harmless by the motion of the water and by the living things in it. Inland[2] cities find the disposal of sewage more difficult. The practice of draining the sewage into a lake or river close by is the cheapest way to dispose of the sewage. This practice does not remove the dangers, especially to cities which may take their water supply farther down the river.

*Small inland cities often dispose of their sewage in a sanitary way by means of large septic tanks with many compartments. The sewage empties from the last compartment into a filter bed, from which it drains as a harmless liquid into the soil or into a stream. The solid materials must be removed from such a septic tank at regular intervals. These can be put into separate tanks where the bacteria complete their destruction, or they can be disinfected and removed to a distance.

*Some large inland cities drain the sewage into great septic tanks which partly purify it. A disinfectant is then added before the sewage is drained away. In other large cities the solid matter is first separated from the liquid. The solid wastes are then put into very large tanks, where they are made harmless by the action of bacteria. The liquid wastes are sprayed into the air where the sunlight and the oxygen in the air will kill some of the germs (Fig. 48, p. 83). The liquid is then allowed to filter through great beds of broken coke,[1] where bacteria continue the purifying process. It is finally filtered through beds of sand and gravel, which complete the process before it is drained away.

---

[1] *Disinfectant* (dis in fek′tant): a substance used to kill the germs of disease.

[2] *Inland* (in′land): far from the ocean.

> *Special Reports.* Discuss the advantages and the disadvantages of the method of sewage disposal used in your town or city, or make a survey of your neighborhood to find the number of farm homes where septic tanks, chemical closets, dry-earth toilets, or cesspools[2] are used.
>
> Why is either the septic tank, the chemical closet, or the dry-earth toilet a better method of disposing of sewage than the cesspool?
>
> Study the construction of the flush tank (Fig. 58) of the toilet and explain its operation.

61. †Sanitation depends upon good plumbing.[3] The plumbing of a house should be so planned and installed that it can easily be examined and repaired at any point. Water pipes may be protected from freezing by wrapping them with some substance that will not conduct heat readily, such as felt or asbestos (Fig. 184, p. 325). Outside pipes, such as those into tanks, are sometimes protected from freezing by first wrapping them loosely with newspaper, then covering the newspaper with felt. The large pipes, or water mains, which carry the water from the reservoirs to the homes are buried far enough below the surface of the ground to prevent the water in them from freezing.

---

[1] *Coke:* the solid which remains after some of the gases have been removed from soft coal.

[2] *Cesspool* (ses′pool): a covered pit in the ground into which the sewage from a house is drained.

[3] *Plumbing* (plum′ing): all the gas, water, and sewer pipes in a building.

†The outlet pipe below the sink, washbowl, wash trays, and bathtub, and in the bottom of the toilet bowl (Fig. 58) is always curved like a siphon (Fig. 36, p. 67). This bend is called a trap. Some water always remains in the trap, thus preventing sewer gas from coming into the house through the drains. All the drains are connected with a pipe called the soil pipe. This pipe leads up through the roof and provides a means of escape for sewer gases. Traps are usually kept clean by flushing[1] them with quantities of water and also by occasionally flushing them with hot water in which lye has been dissolved. Most traps are equipped with a screw cap in the bottom of the bend. This cap can be removed to allow solid matter to be taken out in case the trap becomes closed.

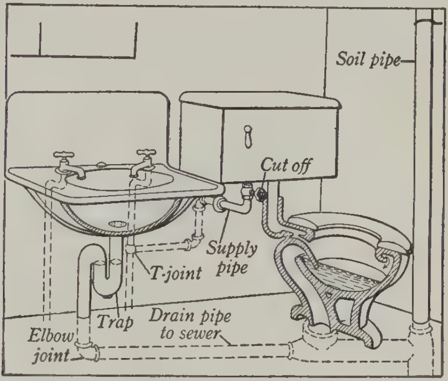

FIG. 58. SOME FEATURES OF MODERN PLUMBING.

Locate the cut-offs, traps, elbow joints, and T-joints in this diagram

†Cut-offs (Fig. 58) make it possible to shut off the water at certain places and to repair plumbing without shutting off the water from all parts of the house. T-joints or elbow joints (Fig. 58) are used to save the labor and difficulty of bending pipes when it is desired to carry the plumbing round corners or to branch from a main pipe.

---

[1] *Flush:* to cause water or other liquid to flow rapidly through a pipe or basin in order to clean it.

Special Reports. How many traps, cut-offs, T-joints, and elbow joints can you locate in your home? How many kinds of materials are used in making pipes for the plumbing of various parts of the house? How are iron pipes protected from rust?

*Faucets are commonly of the two types shown in Fig. 59. A leaky faucet should be repaired at once to prevent waste of water. Usually the leak is caused by the wearing out of the washer.[1] It is not a difficult task to shut off the water from the faucet, screw off the faucet, and put on a new washer in place of the worn one.

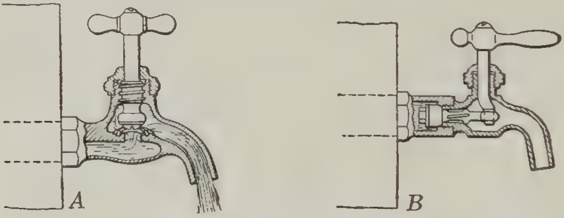

FIG. 59. TWO COMMON TYPES OF WATER FAUCETS

A, compression faucet; *B*, Fuller faucet. Explain how these faucets operate

Special Reports. Find out to what extent water meters are used in your town. What are the relative advantages of the meter plan and the "flat-rate" plan of paying for water used.

TESTS AND GUIDES FOR STUDY AND REVIEW

One new type of statement will be found among the numbered statements below. It contains five possible endings followed by a blank. One of the five may make the statement correct. If so, choose the one which makes the statement correct; but if not, the correct ending must be added in the blank. Examples:

---

[1] *Washer:* a flat rubber or leather ring used in faucets, and where hoses are connected, to prevent leaking. Metal washers are used on screws and bolts.

> Air is mostly composed of oxygen nitrogen argon dust carbon dioxide _____. (*One of the five endings,* ***nitrogen****, is correct and therefore the blank does not need to be filled.*)
>
> Air is mostly composed of oxygen argon water vapor dust carbon dioxide _____. (*None of the five endings given is correct, and therefore* ***nitrogen*** *would need to be put in the blank.*)

1. Hard soaps are made by boiling fats or oils with **water** **chloride of lime** **soda** **turpentine** **sodium hydroxide** _____.

2. Rain water is hard water.

3. Hard water can sometimes be made sufficiently soft for washing purposes by adding **salt** **sodium hydroxide** **oil** **borax** **calcium compounds** _____.

4. Washing powders frequently contain **baking soda** **salt** **magnesium compounds** **turpentine** **calcium compounds** _____.

5. The best method of sewage disposal in country homes which are equipped with running water is **the septic tank** **the cesspool** **the dry-earth toilet** **the chemical toilet** **the common outdoor toilet.**

6. Two satisfactory ways of disposing of body wastes in country homes which are not supplied with running water are the ____ toilet and the ____ toilet.

7. It is never a safe practice for cities to empty their sewage directly into lakes or rivers close by.

8. It is easier to remove stains from clothing if the stains are fresh than if they are old stains.

9. When a faucet leaks, it is usually because the ____ is worn out.

SCIENTIFIC PUZZLES AND GAMES

After each problem you will find five opinions, or answers. See whether you can pick out the best one in each case; that is, the one which a carefully trained scientist would consider best. Then see whether you can find which of the scientific attitudes (see pages 8–10) is illustrated by each problem and the best answer.

Problem 1. Before the Civil War a foreigner visited this country. He landed at Savannah, Georgia, where he saw many more negroes than white people. He returned to his own country and reported that there were considerably fewer whites than negroes in North America.

a. The foreigner's report was founded on fact.
b. His report was founded on facts true only of a limited area.
c. His report was founded on scientific observation.
d. His report was founded on unscientific observation instead of fact.
e. His report was not founded on fact.

Problem 2. You are given a locked padlock and a box containing several hundred loose keys, among which is the key that will unlock the padlock. You are in a hurry to unlock the padlock. Which of the following would probably be the best and quickest way to unlock it?

a. See whether the keyhole looks as if it would require a flat key or a round key to open it. Then try, one after another, all the flat keys or all the round keys until you come to the right key.
b. Try any key that your hand happens to touch. It is as likely to be the right key as any other in the box. If it doesn't happen to fit, toss it aside and try the next key that your hand happens to touch, and so on until you pick up the right one.

c. If it is a big padlock pick out and try, one after another, only the large keys until you come to the right one; if it is a small padlock, do the same with the small keys.

d. Before trying any key in the lock, examine the keyhole carefully. Then pick out all the keys which look as if they would open the lock. Try the most likely-looking one of these first; if it does not fit, try the next most likely-looking one, and so on until you come to the right one.

e. Close your eyes, plunge your hand into the box of keys, and trust to luck to pick the right one. If you do not happen to get the right one the first time, do the same thing again and keep on doing it until you do pick the right one. You are certain to pick the right one sooner or later.

UNIT IV. KNOWING AND USING MATTER, ENERGY, AND WORK

CHAPTER VIII

THE IMPORTANCE OF MATTER

Some Questions this Chapter Answers

What is matter? In what three states does matter exist? What is meant by "inertia"? by "centrifugal force"? How can we prove that matter has weight? What is meant by "density"? by "specific gravity"? What are molecules? How does cohesion differ from adhesion? What is meant by "acids"? "bases"? "salts"? Can matter be created or destroyed?

62. *What is matter? Everywhere in our environment many different kinds of substances, or matter, are found. We see and use these various kinds of matter, such as water, wood, cloth, and the like, so constantly that we take most of them for granted and give attention only to the unusual ones or those which happen to be particularly important to us. Matter is the general name given to all substances of every sort; that is, *matter is anything that occupies space and has weight.*

Experiment 13. Is air matter? Thrust a drinking glass mouth downward into a pan of water. Does the water enter the glass? Can you account for what you see? Why do you think that air is or is not matter? If you have trained yourself to observe carefully, you can answer the following questions and be certain that you are right: How far did the water enter the glass? Not at all? About halfway up? Just a little? Clear to the top? Nearly to the top? Repeat the experiment to make sure whether you are right.

Experiment 14. Is air matter? Weigh a basket-ball carefully before you inflate[1] it. Inflate it and again weigh it carefully. Is the weight the same in both cases? Can you account for what happens? Why do you think that air is or is not matter?

63. *Matter exists as a solid, a liquid, or a gas or vapor. Some substances, such as gold or silver, are known to us only in the solid state. Other substances, such as lead, may be known to us in the solid state and the liquid, or melted, state. Still other substances are familiar to us in all three states. For example, we are familiar with solid cakes of paraffin, with the melted or liquid paraffin which is poured upon the top of jelly in glasses, and with the gaseous[2] paraffin which vaporizes[3] and burns in a candle flame. What are the three states of water (Fig. 60)?

> How many other examples of substances in one or more of the three states of matter can you give?

64. *All matter has inertia. Inertia[4] is the property by which a thing moving keeps on moving in the same direction at the same speed until something stops it, and a thing at rest remains at rest until something makes it move. When you are running and "stub" your toe, you fall forward because your feet are suddenly stopped, but the inertia of the upper part of your body keeps it moving ahead. An automobile gains speed slowly because its inertia tends to keep it where it is, making it hard to start; but, once it is started, it cannot be stopped instantly, because its inertia tends to keep it going (Figs. 61 and 62).

---

[1] *Inflate* (in flate′): to fill with a gas, as air.

[2] *Gaseous* (gas′e us): *vaporous* (va′per us): like a gas or vapor.

[3] *Vaporize* (va′per ize): to change to a vapor.

[4] *Inertia* (in er′shia): the tendency not to change the state of rest or motion unless acted upon by an outside force.

FIG. 60. ANCHORED BESIDE AN ICEBERG

Water can be seen in two of its three states. What is the other one?

Experiment 15. Can you explain these two "tricks"? (1) Place six or eight books in a pile. *Quickly* pull the bottom book from under the rest. If you do this quickly enough, the rest of the books simply drop down without falling apart. Explain. (2) Place a coin upon a card over the open end of a water glass. Quickly snap the edge of the card (Fig. 62). What happens? Explain.

65. †Centrifugal force. When you ride on a merry-go-round you tend to lean outward as the merry-go-round

FIG. 61. USING SCIENCE IN SPORTS

The man runs rapidly, then jumps as *high* as he can. His inertia carries him forward

whirls. The faster it whirls, the more do you tend to lean outward. Also when lemonade is stirred round and round in a pitcher, the liquid likewise is forced outward from the center of the pitcher. If you tie a piece of lead to a string and then whirl the lead round your head while holding the end of the string, the lead will pull harder and harder against the string the faster it is whirled. The lead may even break the string. If it does, the lead starts off in the same straight line in which it happened to be moving when the string broke.

†These are examples of centrifugal force. *Centrifugal force is the tendency*[1] *for all parts of a whirling body to move outward from the center.* Can you give other examples of centrifugal force?

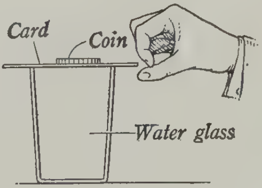

FIG. 62. COIN AND CARD "TRICK"

Would the result be the same if the card were slowly pushed off as when it is snapped off? Explain

---

[1] *Tendency* (ten′den sy): quality of being ready to act in a certain way rather than otherwise.

66. *All matter has weight. If an object is dropped, it always falls "down"; that is, toward the center of the earth. The earth attracts every object on or near it. This attraction is called *gravity.* The more matter a body has in it, the greater is its weight, because gravity pulls upon every particle of matter in the body. Nobody yet knows what *gravity* or *gravitation*[1] is or what causes it. We shall learn when we study astronomy in Unit VII, however, that heavenly bodies attract each other, and that this attraction is the force which holds the earth and the other planets in their paths around the sun.

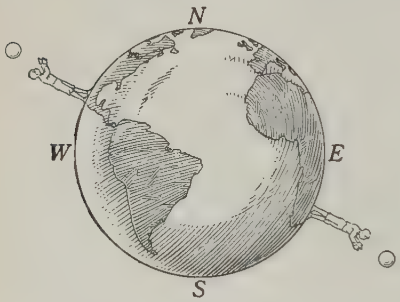

FIG. 63. WHICH DIRECTION IS UP?

> Imagine two boys, one in the United States and the other exactly halfway round the world from him. Each tosses a ball "up" into the air at the same moment (Fig. 63) and catches it as it comes "down." Do the two balls move in the same direction or in opposite directions? Suppose people in Alaska, France, Australia, and Argentina are all looking "up" at airplanes at the same time. Do they all look in the same direction to look up? Which direction is "up"?

67. *All matter has density. *The density of any substance is the number of pounds a cubic foot of that substance weighs.* Thus the density of water is 62.4 pounds per cubic foot, because a cubic foot of water weighs 62.4 pounds.

---

[1] *Gravitation* (grav i ta′shun): the term "gravity" is often used in place of "gravitation," the attraction any body has for every other body. *Gravitational* (grav i ta′shun'l): due to gravity.

The density of ice is 57.4 pounds per cubic foot. Scientists express density in metric units (see page 144). Sometimes the term "specific gravity" is used instead of density, although the terms do not have the same meaning. *The specific gravity of a substance is its weight compared with the weight of an equal volume of water.* Thus the specific gravity of ice (Fig. 64) is 0.92, which means that a cake of ice of any size or volume weighs 0.92 as much as an equal volume of water. Usually when people say that one substance is heavier than another, they mean that the first substance has a greater density, or a greater specific gravity, than the other.

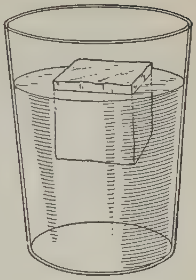

FIG. 64. ICE FLOATS

If the specific gravity of ice were more than 1.00 would it float? Explain

FIG. 65. UNITED STATES NAVY SUBMARINE ON THE OCEAN SURFACE

In what ways is a submarine like a dirigible (Fig. 6, p. 17)?

Thus when we say that mercury is heavier than water we mean that mercury is denser than water, or that it has a greater specific gravity than water; that is, we mean that a cubic foot of mercury weighs more than a cubic foot of water, or that any given volume of mercury is heavier than an equal volume of water.

The submarine [1] furnishes a good illustration [2] of density and specific gravity. When the submarine is floating on the surface (Fig. 65) it has, like any other boat, an average density and specific gravity less than the density and specific gravity of water. The average density and specific gravity of the submarine must be increased before it can sink below the surface. Water is therefore allowed to enter the ballast tanks until the average density and specific gravity of the submarine are only slightly less than the density and specific gravity of water. The submarine now barely floats. Before the submarine can float on the surface again its average density and specific gravity must be reduced. This reduction is accomplished by forcing the water out of the ballast tanks by means of compressed air (Chapter III).

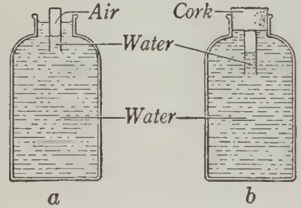

FIG. 66. DIAGRAM OF A "BOTTLE SUBMARINE"

Project.[3] To make and study a "bottle submarine." Fill a bottle, such as a "pop" bottle, a catchup bottle, or an olive bottle, entirely full of water. Fill another *very small* bottle about half full of water. Keeping your little finger over the mouth of the small bottle, invert it in the larger one so that the small bottle barely floats, bottom up, in the big one (Fig. 66, *a*). You may need to try several times, using a different amount of water in the small bottle each time, before you get the smaller bottle to float in the way shown in the figure. *Lightly* push a cork into the larger bottle, and at the same time force the smaller bottle down into the larger one (Fig. 66, *b*). The smaller bottle now represents a submarine at the surface of the ocean. Press down firmly upon the cork. What happens? Can you make the submarine go down or come up by changing the pressure on the cork? As you press upon the cork, carefully observe the submarine. Release the pressure on the cork and again observe the submarine. Can you explain why it sinks and rises? If you have been successful in carrying out this project, you have illustrated several of the scientific attitudes (see pages 8–10). Can you name these?

---

[1] *Submarine* (sub ma reen′): under the ocean; a ship which can travel beneath the ocean surface.

[2] *Illustration* (il us tra′shun): anything used to make an idea clear (for example, a picture, a drawing, a diagram, or an object; a story or an incident may also serve as an illustration).

[3] An experiment suggested by Mr. M. R. Van Cleve.

Carve the figure of a man out of wood. Put tacks on its feet so that it will barely float. Can you make it sink and rise in the bottle in the same way that you did the "bottle submarine"?

68. What are molecules? All matter of every sort is now known to be composed of very small rapidly moving particles called molecules.[1] These molecules are much too small to be seen with the eye; in fact, it would take many thousands of them together to make a speck large enough to be seen with the strongest microscope (see page 7); yet, marvelous as it sounds, scientists have been able to determine their size, their weight, and the speed with which they move.

When matter is in the solid state the molecules are thought to be packed closely together. In the liquid state they are thought to be farther apart and to move about, over, between, and round each other easily. In the vaporous, or gaseous, state they are very great distances apart, in comparison to their size. A great scientist has computed[1] that if the molecules in a cubic inch of air could suddenly be made as large as fine grains of sand, they would fill a trench three feet deep and a mile wide extending from San Francisco to New York.

---

[1] *Molecule* (mol'e kule): smallest part of a substance that can exist by itself.

Molecules of water are like one another and molecules of iron are alike, but molecules of water are not like molecules of iron. In fact, molecules of one kind of matter are never exactly like the molecules of any other kind. For this reason different kinds of matter have different characteristics or properties. Thus different kinds of substances have different colors, sizes, and shapes. Some are harder or softer; some are more easily bent or twisted; some are more easily pressed or hammered out of shape; some are better or worse for certain purposes than other kinds of matter, usually because the molecules composing the different substances are different. Sometimes, however, the molecules composing two different samples of matter are exactly the same, as in the case of water, ice, and water vapor; yet their properties are different, because the molecules are arranged differently in the different states of the same kind of matter. Coal and diamond are made up of the same kind of molecules arranged differently; that is, they both consist of carbon and of nothing else.

A knowledge of molecules helps us to understand elements, compounds, and mixtures (see page 51). Every portion of an element is exactly like every other portion of the same element, because the element is composed of only one kind of molecules. Every portion of a compound is exactly like every other portion of the same compound, for the same reason. But although the molecules of the compound are all alike they are not simple, like the molecules of elements, for the molecules of compounds contain still smaller particles of different elements. Thus the molecule of the compound water contains particles of the two elements oxygen and hydrogen. Different portions of mixtures are not alike. Thus sugar dissolves in water to form a mixture. Sugar and water molecules are scattered among each other but are not combined. Similarly, in Experiment 7, p. 53, some of the molecules of alcohol found places between the molecules of water.

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[1] *Compute* (kom pute'): to reckon; to work out with figures, as a problem.

69. †Cohesion and adhesion. We know that water molecules stick together to form drops, that the molecules of iron stick together to form bars or other pieces instead of falling apart in a powder, that the molecules of chalk stick together in a piece of chalk, and so on. When molecules of the same kind stick together, they are said to *cohere.* Cohering, or *cohesion* as it is usually called, is therefore *the sticking together of the same kind of molecules.*

†We know also that molecules of one kind often stick to molecules of another kind. Thus water sticks to the surfaces of most objects, making them wet; chalk sticks to the surface of the blackboard when we write on the board; oil sticks to the surfaces of parts of machinery. When molecules of different kinds stick together, they are said to *adhere.* Adhering, or *adhesion* as it is usually called, is therefore *the sticking together of different kinds of molecules.*

How many examples of cohesion and adhesion can you see in the room where you are now sitting? State which of the following are examples of adhesion and which are examples of cohesion: sugar in a piece of candy; candy sticking to your fingers; glue holding two pieces of paper together; glue in a tube. How many other examples of cohesion and adhesion can you write down in five minutes?

70. *Acids, bases, and salts are important in chemistry. You are familiar with the sour taste of lemons and vinegar. These are acids. Acids have a sour taste [1] and cause blue litmus paper to turn red. You are probably also familiar with the peculiar biting taste of soda. Soda is a base. Bases are never sour, and they cause red litmus paper to turn blue. Other substances, such as table salt, have no effect on litmus paper. We shall have occasion to refer to acids, bases, and salts in the pages that follow.

Experiment 16. Which of a number of common substances are acids? Which are bases? Which are salts? Test a number of common substances, such as fruit juices, limewater, table salt, with strips of red and blue litmus paper. Make a list of the substances, stating which you found to be acids, bases, or salts.

71. Can matter be created or destroyed? It is true that matter can do several things which sometimes make it seem as if it had been destroyed and new things created. (1) It can be changed from one state to another (see page 107); (2) it can be changed in form and appearance; (3) it can combine with other kinds of matter to form still different substances. Matter can never be destroyed in the sense that it no longer exists, nor can new matter be made out of nothing and added to the matter that already exists. For example, you have seen displays of fireworks at a Fourth-of-July or other celebration. You have afterward, perhaps, examined the burned-out tube of a Roman candle (Fig. 23, *c*, p. 50). The tube appeared to be empty; for the solid matter — the gunpowder which had occupied the hollow of the tube — had been removed and air had taken its place. You might have thought, What became of the powder? At the time that the Roman candle was going off the solid powder was being transformed (changed) mostly into the gaseous state. This gas became scattered about in the air. All the solid matter which had occupied the tube still existed somewhere, however, even though you could no longer locate or recognize it.

---

[1] Many acids and bases are so strong that it is not safe to taste them.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. Every object which I can see in this room is matter.
2. There are no kinds of matter which cannot be weighed.
3. There are no kinds of matter which cannot be seen.
4. If you drop your book, it falls to the floor because of **inertia friction gravity centrifugal force density ____.**
5. If you give a chair a push, it continues to slide for some distance across the floor because of its ____.
6. A cubic foot of ice weighs 57.4 pounds. The ____ of ice is therefore 57.4 pounds per cubic foot.
7. The specific gravity of aluminum is nearly 2.6. This statement means that a cubic inch of aluminum weighs 2.6 times as much as a cubic inch of water.
8. Air is made up of molecules.
9. The juice of grapefruits and oranges is a base.

CHAPTER IX

THE IMPORTANCE OF ENERGY AND WORK

Some Questions this Chapter Answers

What progress has man made in learning to control energy? What is meant by "energy"? Can energy be created or destroyed? What are the sources of the earth's energy? How is energy related to force and work? What is force? What is work? What is friction? How is friction reduced? What are some ways in which friction is useful? What are some ways in which friction is not useful? How can we determine how much work is done?

72. †Man learning to control energy. Ages ago man learned that merely with his own hands and body he could not do many things which he wanted to do. Being more intelligent than the lower animals, he sought ways of securing the use of other stores of energy besides his own. Little by little he learned to tame various kinds of animals and train them to do the heavier work for him. When he was successful in his combats he sometimes made captives of his enemies and made them use their energy in working for him. Little by little he learned to make use of some of the natural sources of energy. He learned to make the water from streams turn his rude mills. He learned to use the energy of fire to cook his food. Until very recently, however, he still depended for most of his energy upon men and animals (Fig. 67). Within very recent times scientists have learned to know and to use hitherto-unknown sources of energy, such as electricity[1] and radio (Units XII and XIII).

73. *Energy the capacity to do work. Any portion of matter — for example, an animal, a rock, a boilerful of steam (Fig. 350, p. 638), or whatever it may be — has energy if it is able to move or to cause something else to move. Some bodies of matter have energy because they themselves are moving, and by striking other objects could cause them to move. Other bodies of matter, which are not themselves moving, have energy stored in them because of their chemical nature or because of their position or condition. *The energy possessed by moving bodies of matter is called kinetic energy; stored energy, or energy of*

FIG. 67. THE GREAT PYRAMID OF EGYPT

This was built in 2900 B.C. under the direction of an Egyptian king, who used the energy and hand labor of thousands of slaves

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[1] *Electricity* (e lek tris′i ty): the form of energy appearing in electric currents.

position or condition, is called potential energy (Fig. 68). When you kick a football your foot has kinetic energy because it is moving and causes the football to move.

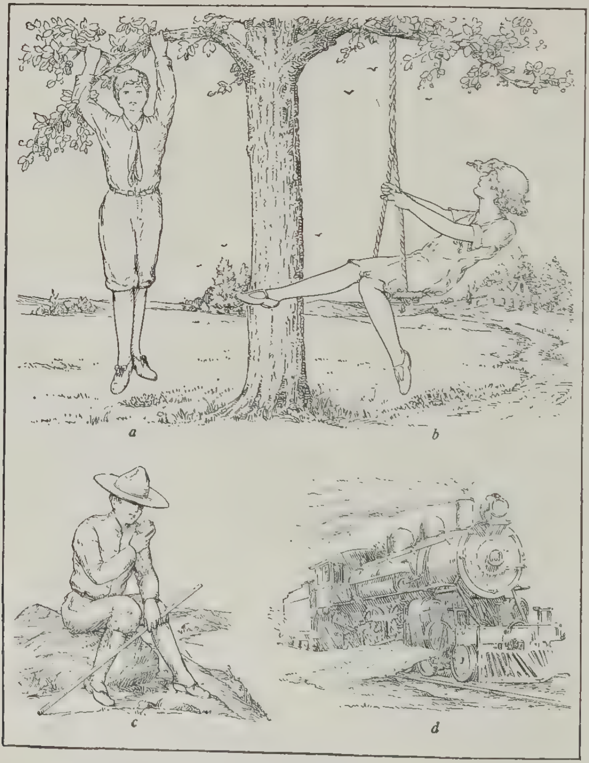

FIG. 68. KINETIC AND POTENTIAL ENERGY

How many examples of kinetic and potential energy can you find in these pictures?

The moving football has kinetic energy and knocks the molecules of air aside as it travels through the air. When it is above the earth it also has potential energy because it is in position to fall. Finally all its energy, both kinetic and potential, is used up and it comes to rest on the ground. Wind possesses kinetic energy because as it moves it can move ships and windmills. Gasoline, coal, cooking gas, and food are all forms of potential energy because of their chemical nature.

Other examples of potential energy are a rock which is perched on the top of a hill, and which therefore has potential energy because it can roll down the hill; a stretched rubber band, because if one end is released it can do work upon itself or upon something else as it contracts; a watch spring after it has been wound, because as it slowly unwinds it is in condition to move the wheels of the watch; a bent bow, because it is in position, if released, to do work upon the arrow in making it fly through the air; compressed air, because it is in condition to move and to cause objects to move when it is released.

We now know of several forms of energy besides stored (potential) energy and the energy of moving bodies (kinetic). Some of these are current electricity, radio, light, and heat. There are still others which are known and probably others not yet discovered.

How many other examples of kinetic and potential energy can you list in five minutes?

74. *Energy cannot be destroyed but can be changed in form. In this respect energy is like matter. Thus, before the Roman candle (Fig. 23, *c*, p. 50) was lighted, the powder in it had chemical (potential) energy; while it was going off this potential energy was transformed into several kinds of energy, such as heat, light, sound, and the kinetic energy of moving fire balls and sparks. The Roman candle also had potential energy while it was being held above the ground. This potential energy was transformed into kinetic energy when the candle was tossed to the ground. We burn coal (potential energy) to produce steam (heat energy) to turn the armature of a dynamo (Chapter XXX) (mechanical[1] energy), thus producing electricity (electrical[2] energy), which lights our lamps (light and more heat energy), turns armatures (mechanical energy), heats flatirons (heat energy), and so on (Fig. 69).

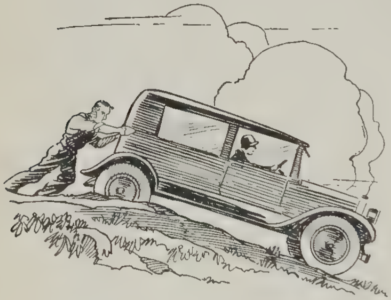

FIG. 69. DIFFERENT KINDS OF ENERGY

What kind of energy has this automobile just before it starts downhill? What kind does it have when it is running down the hill? When the automobile was going up the hill, kinetic energy was being changed to potential energy. As it goes down the hill potential energy will be changed to kinetic energy

75. *Nearly all the energy on the earth comes from the sun. The moon is the source of a small portion of the earth's energy, since it is the principal cause of tides. The earth possesses some energy of its own in its heated interior. These two sources are insignificant,[3] however, compared with the enormous stores of energy received directly and indirectly from the sun. The earth receives only an exceedingly small part of all the energy which the sun is constantly sending out in all directions through space. Yet this energy that we receive from the sun furnishes us with heat and light, without which no life would be possible. The heat energy from the sun causes unequal heating of the different parts of the earth, thus causing the winds and ocean currents. It also sends us another form of energy which produces important chemical effects, such as photography and the fading of cloth and wall paper. It evaporates water, thus making possible the rains, the streams and rivers, and the waterfalls. It acts upon chlorophyll[1] in green plants and thus directly and indirectly makes possible all the food in the world.

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[1] *Mechanical* (me kan′i kl): having to do with moving matter, particularly machinery.

[2] *Electrical* (e lek′tri kl): having to do with electricity in its various forms.

[3] *Insignificant* (in′sig nif′i kant): of very little importance.

Can you trace step by step back to the sun the energy of an electric lamp? the energy in a loaf of bread?

New uses of energy are constantly being discovered and applied to every portion of modern life. The scientists are not content merely with inventing new ways of using the sources of energy which are already at hand: they are constantly seeking to discover new sources. We might summarize[2] the importance of energy by stating that probably the chief problem of the scientist today is to discover hitherto-unknown sources of energy, to devise[3] new uses of energy by which to make the world a more pleasant and more convenient place to live in, and to enable us to get more value out of the energy we use.

76. *Energy is closely related to force and work. Whenever you push or pull some object, you exert a force upon it. Gravity is the force which tends to pull all objects toward the center of the earth; in fact, *a force is a push or a pull.* Whenever you push or pull some object and succeed in making it move, or whenever you succeed in stopping some object that is moving, you have done *work*. In the strictly scientific sense, however, you never do any work *unless* you succeed in moving something or stopping something that is already moving. You may push or pull as long and as hard as you please; but if you do not succeed in moving the object upon which you are exerting the force, you have not done any work at all. Thus, you may sit quietly studying, or you may hold a heavy object above the floor, or you may push against the wall until you are exhausted, without doing any work whatever in the scientific sense, because you have not moved anything. In each case you have exerted force and have used up energy, but you have done no work. This scientific definition [1] of work may seem somewhat puzzling to you. It is, nevertheless, the definition which is used in connection with all engineering and all machines of every sort.

---

[1] *Chlorophyll* (klo′ro fil): the green material in plants.

[2] *Summarize* (sum′a rize): to make a summary; that is, to make a brief statement of the important points or ideas.

[3] *Devise* (de vize′): to think out or study out.

In Fig. 69 is the man exerting a force? Is he expending energy? Is he doing work? If he finally succeeds in moving the automobile, will he have done work? What kind of energy do objects have when work is being done on them?

77. ***Whenever work is done there is friction.*** We think of the surface of a window glass or of a planed board as being perfectly smooth. It is not. No surfaces are perfectly smooth. Whenever two surfaces rub together, therefore, there is always resistance [2] to the motion. *This*

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[1] *Definition* (def i nish′un): an explanation or description of a word or thing.

[2] *Resistance* (re zis′ tunce): opposition to motion, action, force, or effort.

resistance to the movement of one object upon the surface of another is called friction.

*Friction always produces two effects: (1) some of the mechanical energy of the moving object is always transformed into heat energy and (2) some of each surface is always worn away. Thus when you rub your finger rapidly back and forth on your sleeve, both the cloth and your finger become hot. The rougher the cloth or the faster you move your finger, the warmer both the cloth and your finger become. Try this. If you continued the rubbing long enough the cloth would wear through and the skin of your finger would be worn off. What happens when one slides rapidly down a rope?

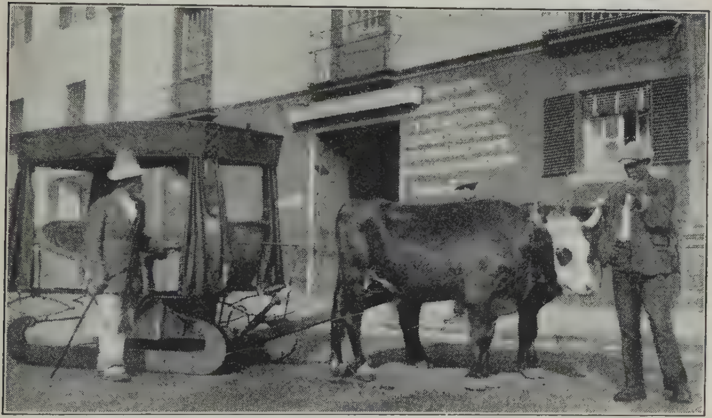

FIG. 70. AN OX-CARRIAGE IN THE MADEIRA ISLANDS

Is there much or little friction when this vehicle is pulled along? Explain. The driver carries a piece of coarse cloth soaked in oil. He lays this cloth in front of one runner. After the sled has passed over the cloth he puts it in front of the other runner. Thus he reduces friction. Explain

We are apt to think of friction as something which is always undesirable, since it uses up some of the energy and since it causes machinery to wear out. It is true that we usually try to reduce friction in machinery. One way to do this is to pour oil into the parts that rub together (Fig. 70). The oil reduces the friction because it keeps the surfaces from touching. Another way to reduce friction is to make things roll rather than slide, because there is less friction when things roll against one another than when they slide. For this reason small wheels are put on furniture legs; wheels instead of sled runners are put on railroad cars; ball bearings and roller bearings are used in automobiles, bicycles, and other machines (Fig. 71).

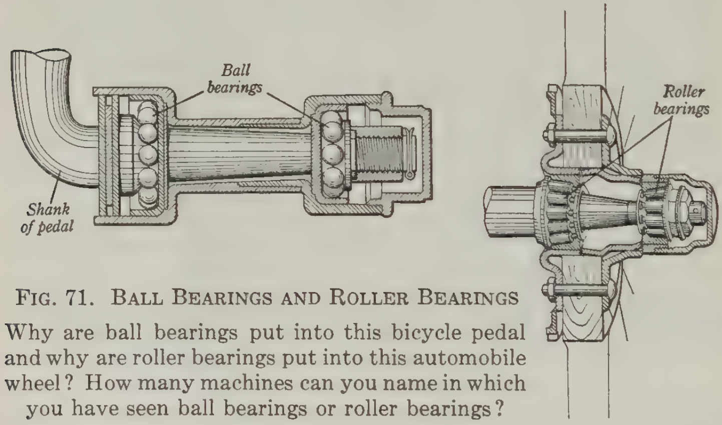

FIG. 71. BALL BEARINGS AND ROLLER BEARINGS

Why are ball bearings put into this bicycle pedal and why are roller bearings put into this automobile wheel? How many machines can you name in which you have seen ball bearings or roller bearings?

*But although too much friction is undesirable, friction is very important and necessary in our daily life. Thus the housewife uses a lemon-grater[1] to increase the friction when she wants to wear away the skin of the lemon. If it were not for the friction between your shoes and the floor you could not walk out of this room; if it were not for friction the nails in the ceiling would fall out; if it were not for friction the automobile brakes would not stop the wheels.

---

[1] *Er* or *or* on the end of a word means "one who" or "that which" does the act stated in the word. Thus *grater* means "that which grates"; *inventor*, "one who invents something."

Why are sand and ashes sometimes spread on icy sidewalks? Can you give other examples of useful friction? How many examples can you give of undesirable friction?

When you lift an object you must exert upon it a force slightly greater than its weight. Thus, when you lift a book weighing two pounds

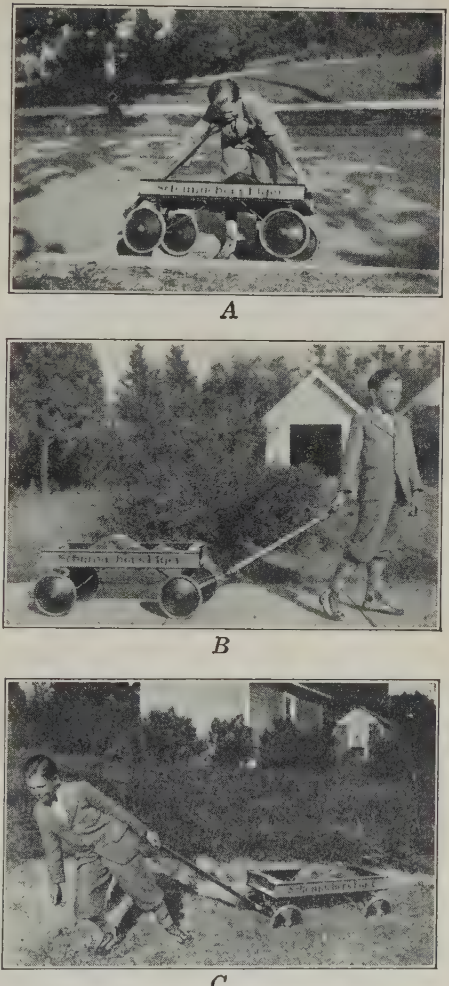

FIG. 72. GETTING WORK DONE

Is the boy using up energy and doing work as well as exerting force in all three pictures?

you exert a force of slightly more than two pounds. If you move an object without lifting it, you sometimes exert a force smaller than the weight of the object and sometimes a force greater than its weight. Thus, in Fig. 72, *A*, the boy is exerting a force equal to the weight of the wagon and its load because he is lifting them; in Fig. 72, *B*, he is exerting a much smaller force than the weight of the wagon and its load because he needs to exert only enough force to overcome the rolling friction of the wheels on the walk; in Fig. 72, *C*, he is exerting a force much greater than the weight of the wagon and its load. Why?

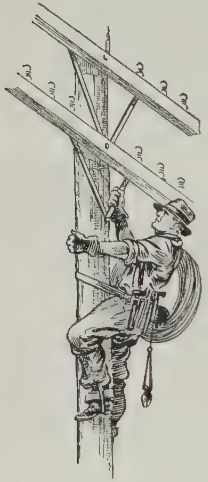

FIG. 73. ENERGY AND FORCE AND WORK

The workman has energy, exerts force, and does work. Explain. In what ways does he use friction to prevent his falling?

78. *Force times distance equals work. To find how much work is done upon an object which is moved, we multiply the force exerted in moving it by the distance it is moved. Thus, in Fig. 72, *A*, if the curb is 1 foot above the street, the boy in lifting his 50-pound wagon 1 foot does 1 × 50 = 50 *foot-pounds* of work. In Fig. 72, *B*, each time that he pulls his wagon forward 2 feet while he exerts a force of 10 pounds, he does 2 × 10 = 20 foot-pounds of work. In Fig. 72, *C*, every time that he succeeds in pulling his wagon forward 2 feet while he exerts a force of 60 pounds, he does 2 × 60 = 120 foot-pounds of work.

This will enable you to understand what is meant when foot-pounds of work are spoken of and to figure the amount of work done when you know the force and the distance.

If the man in Fig. 73 weighs 150 pounds and climbs 20 feet up the pole, how many pounds of force must he exert in lifting himself? How many foot-pounds of work must he do upon himself in climbing 20 feet? While he is climbing, what kind of energy has he? When he stops climbing, what kind of energy will he have?

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. A moving automobile always has potential energy.
2. A loaf of bread and a gallon of kerosene are two examples of ____ energy.
3. The sun is the source of nearly all the energy on the earth.
4. When a ton of coal is burned, the energy is not lost but is changed to some other form of energy.
5. If you were to try to lift a truckload of coal with your hands you would be exerting a ____, but you would be doing no ____.
6. If while an automobile is going fast the brakes are set so that the wheels slide, the tires become hot and are worn away rapidly because of **inertia friction work energy molecules** ____.
7. Chains are sometimes put on automobile tires when there is ice or snow on the streets or when the roads are very muddy, in order to increase the ____.
8. If a grocer lifts a 50-pound sack of flour 3 feet from the floor to the counter, he has done 50 × 3 = 150 foot-pounds of work.

CHAPTER X

MAKING MACHINES HELP US

Some Questions this Chapter Answers

How do modern methods of doing work differ from those used in ancient times? How do machines help us to do work? What are the six types of simple machines? How may work be done to advantage with a lever? a pulley? a wheel and axle? an inclined plane? a wedge? a screw? How may the same object be used as two different machines? How may two machines be made to work together as one? What is meant by a "labor-saving device"? What is meant by the "efficiency of a machine"? How does the power of a machine affect the time required for it to do work? What are the important features and advantages of the metric system?

79. Ancient and modern work. Ancient man did practically all the work he had to do by moving objects with his own hands or by forcing his domestic animals or captives to carry and drag objects for him. Little by little, just as he learned to use stores of energy besides his own, he learned how to make rude machines to assist him in handling and moving the heavier objects about him. By means of these machines he was able to build better dwellings, to cultivate his fields better, to wage war more successfully — in fact, to do all his various tasks better and more easily. After thousands of years man had learned to build such marvelous structures[1] as the pyramids of Egypt (Fig. 67, p. 119) and the Colosseum of Rome. Even these were largely built by the work of animals and slaves with the help of a few rude machines.

Only within recent times has man perfected and combined the various machines for doing his work which make possible the great structures and the comforts of our everyday life. Even today, in many highly civilized[2] countries such as China and Japan, and in rural Europe and America, much of the work is done by man or beast (Fig. 74). The United States, however, leads the world in the use of machines, and our scientists and inventors are constantly devising new ones.

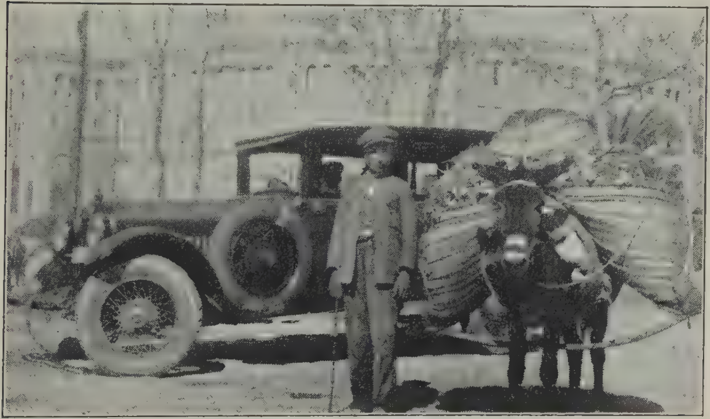

FIG. 74. TWO WAYS OF DOING WORK

A vegetable dealer and a modern automobile in Grenada, Spain. What advantage has the machine over the donkey?

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[1] *Structure* (struk′chur): something built, as a building, a bridge, or other work of engineering.

[2] *Civilize* (siv′i lize): to teach better ways of living. *Civilization* (siv i-li za′shun): progress in learning better ways of living.

80. *Ways in which machines help us to do work. When asked to name some common machines you doubtless think of the automobile, the airplane, the locomotive, the sewing machine, the farm tractor (Fig. 75), the lawn mower, the concrete[1] mixer, the derrick, the elevator.

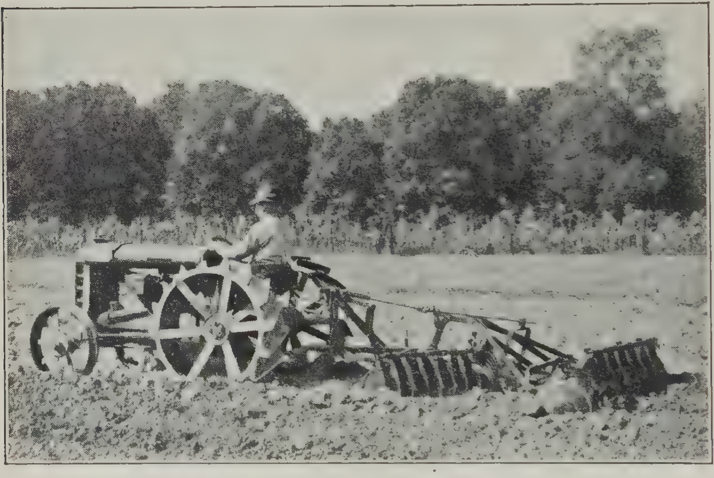

FIG. 75. A MODERN FARM TRACTOR

What work is being done by this machine?

How many machines can you list in five minutes?

*We find that every machine serves one or more of the following purposes, though no machine can serve them all.

a. *Some machines enable us to overcome enormous resistances by exerting much smaller forces than would be necessary without them. The electric shovel (Fig. 76) and the derrick are machines of this type.

---

[1] *Concrete* (kon'krete): sand, gravel, coarse pebbles, or crushed stone held together by cement.

b. *Some machines enable us to do useful work more quickly than it could be done without them. The lawn mower, the farm tractor (Fig. 75), the automobile, the elevator, and the concrete mixer are machines of this type.

c. *Some machines enable us to exert a force in one direction to move an object in another direction. The derrick and the lawn mower are machines of this type.

d. *Some machines enable us to do useful work much more evenly and accurately than it could be done without them. The sewing machine and the concrete mixer are machines of this type.

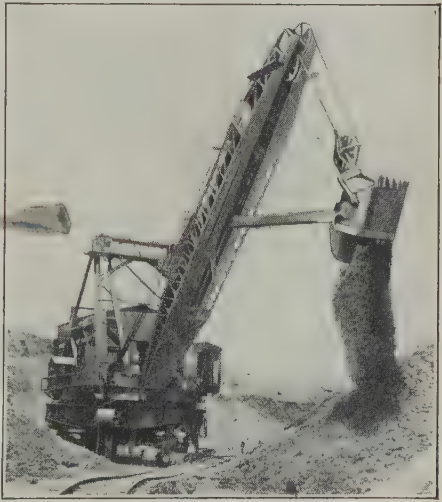

FIG. 76. A LARGE ELECTRIC SHOVEL

Note the size of the man compared with that of the shovel. What work is being done by this machine?

Take the complete list of machines which you made, and see whether you can determine which of these four uses of machines each serves.

81. *Types of simple machines. We naturally think of machines such as those we have been discussing as if each were just one machine; actually they are compound machines made up of many simple machines working together. When we examine the compound machines carefully we discover that there are really only a few different types of machines. There are, in fact, only *six* different types of simple machines: the lever, the pulley, the wheel and axle (or windlass), the inclined plane, the wedge, and the screw (Fig. 77). Compound modern machines are all combinations of these six types.

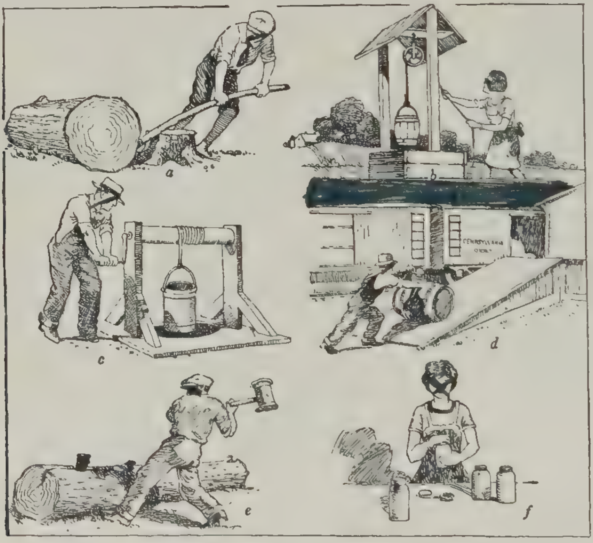

FIG. 77. EXAMPLES OF THE SIX TYPES OF SIMPLE MACHINES

a, lever; *b*, pulley; *c*, wheel and axle, or windlass; *d*, inclined plane; *e*, wedge; *f*, screw. Can you give another example of each?

82. *The lever. It is easy to see from Fig. 77 that a lever is a stiff bar or pole which turns, or pivots,[1] on a point. We call this pivoting point of a lever a *fulcrum*. Simple levers are not always exactly like the one in Fig. 77, *a*. Sometimes the fulcrum is between the force and the resistance, as in Fig. 77, *a*; sometimes it is at one end, with the resistance between the force and the fulcrum,

[1] *Pivot* (piv′ut): to swing, like a hinge, on a point.

as in the potato ricer in Fig. 78, *a*; sometimes it is at one end, with the force between the resistance and the fulcrum, as in the fishpole in Fig. 78, *b*; sometimes the lever is crooked instead of straight, like the clawhammer in Fig. 78, *c*.

We can discover other interesting facts about levers by examining these pictures of familiar levers. In the case of the clawhammer the force exerted by the hand is not nearly so great as the resistance of the nail, but the force moves much farther than the resistance. This statement is also true for the potato ricer: the hand (the force) moves farther than the plunger (the resistance). With the fishpole the opposite is the case: the resistance (the fish) moves farther than the force (the boy's right hand), but the resistance is not so great as the force; that is, the boy must exert more than two pounds of force to land his two-pound fish. With these levers, if the force is smaller than the resistance, it must move farther than the resistance; if the resistance is smaller than the force, however, it must move farther than the force.

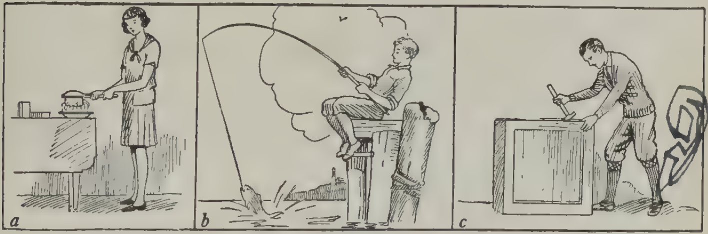

FIG. 78. SOME COMMON LEVERS
For what purposes are levers used?

Is this last statement true of the lever shown in Fig. 77? In how many of the ways in which machines help to do work, listed on pages 132–133, do the various levers in Figs. 77 and 78 help?

Are these last two statements about levers true also for the other types of machines described in the following pages?

83. *The pulley. Fig. 79 illustrates two uses of the pulley: the pulley at the top is called a *fixed pulley* because it remains where it is while being used to lift the weight, or resistance; the lower pulley is called a *movable*[1] *pulley* because it moves with the resistance. Fixed pulleys always serve one purpose only: they make it possible to exert a force in one direction to move a resistance in another direction (see "Ways in which machines help us to do work," pp. 132–133).

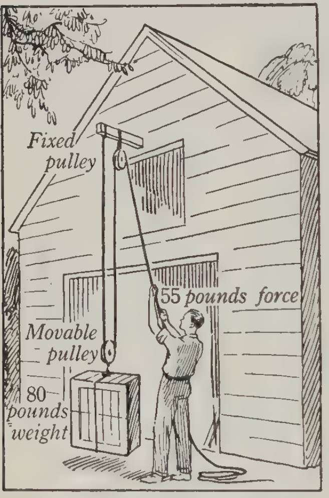

FIG. 79. THE FIXED PULLEY AND THE MOVABLE PULLEY

Why is it better to have the pulley turn than it would be to have the rope slide over it without its turning? Why is the force applied given as 55, instead of 40?

*The movable pulley with the box attached moves upward only half as fast as the man's hands move downward, because the man must pull two feet of rope through the fixed pulley for every foot that the box rises. If there were no friction in these pulleys the man would have to exert a force of only forty pounds to lift the eighty-pound box, because the force moves twice as far as the resistance.

---

[1] *Able* at the end of a word means "that can" or "having the power." Thus *movable* means "that can move" or "that can be moved," "able to move" or "able to be moved"; *usable* means "able to be used."

Of course there is considerable friction in the two pulleys, and therefore the man must actually exert a force of fifty-five pounds.

*In moving heavy objects with pulleys combinations of pulleys are used (Fig. 80). Each combination of pulleys is called a pulley block, and the arrangement of pulley blocks with their ropes is called a block and tackle. A block and tackle enables one to move a heavy resistance with much smaller force, because the force moves so much farther than the resistance (see "Ways in which machines help us to do work," pp. 132–133).

Can you find a block and tackle in Fig. 76, p. 133?

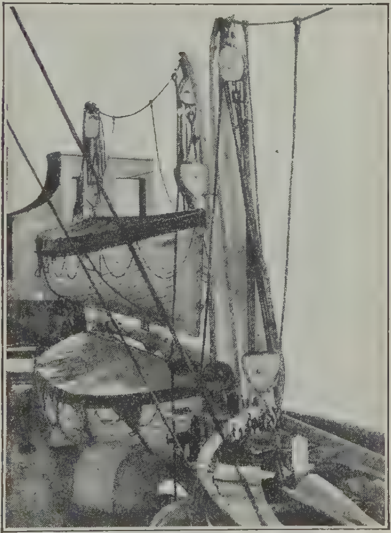

FIG. 80. PULLEY BLOCKS ARE USED TO RAISE AND LOWER THE LIFEBOATS ON SHIPS

How many pulley blocks are used at each end of the boat? Are they fixed or movable pulley blocks?

84. †Wheel and axle, or windlass. With a wheel and axle (Fig. 81) the force is usually exerted on the rim of the wheel in order to move the resistance, or weight, that is attached to the axle. In the steering wheel the wheel is complete; but in the fishing reel we have only one spoke of the wheel, which is the handle of the reel, and all the force is exerted on the end of this spoke. In both illustrations of the wheel and axle shown in Fig. 81 the force is much less than the resistance, because it travels much farther; in Fig. 87, *c*, p. 141 the force applied by the lever to the handle of the grindstone is greater than the resistance on the axle (the rim of the grindstone), because the rim of the grindstone travels farther than the force.

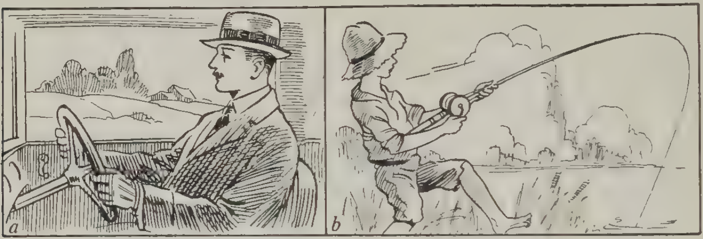

FIG. 81. THE STEERING WHEEL AND THE FISHING REEL ARE TWO FAMILIAR EXAMPLES OF THE WHEEL AND AXLE

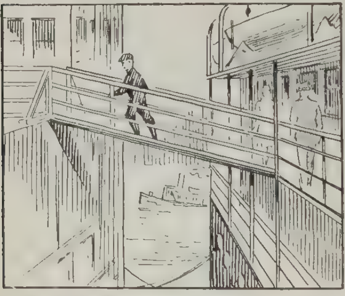

FIG. 82. AN INCLINED PLANE

In which of the ways that machines help us does this inclined plane serve?

85. †The inclined plane. In Fig. 82 the boy is using an inclined plane to raise himself to the level of the dock. He does not have to exert so much force as his weight, because he has to travel farther up the incline than would be necessary if he lifted himself straight up from the boat to the dock. A mountain road is an inclined plane (Fig. 83) to make the slope more gradual.

Can you find other ways in which machines help us to do work by use of the inclined plane?

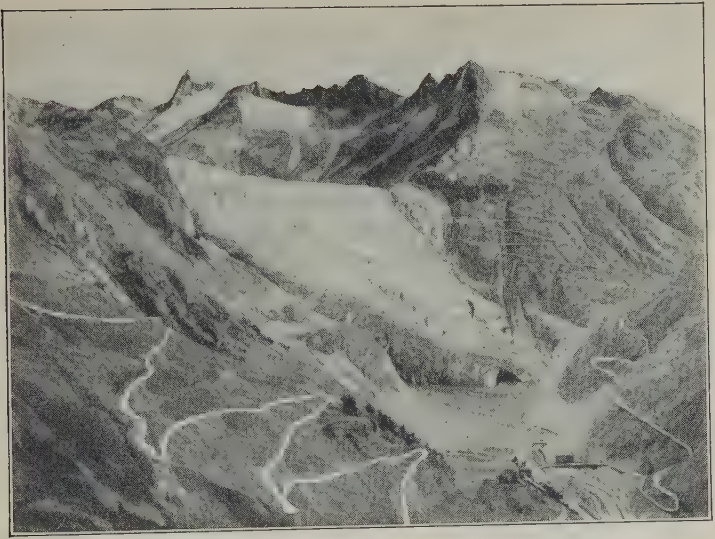

FIG. 83. A MOUNTAIN ROAD IS AN INCLINED PLANE
Photograph by Dr. E. G. Keller

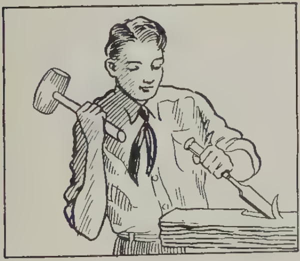

FIG. 84. A FAMILIAR FORM OF WEDGE

How is a chisel like an ax or a hatchet?

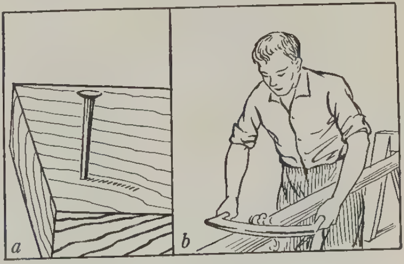

FIG. 85. COMMON WEDGES

The nail (*a*) and the draw-knife (*b*) are wedges. Can you think of other examples of the wedge?

86. †The wedge. The chisel is a simple form of wedge (Figs. 84 and 85). The wedge is only a movable inclined plane. As it is forced into the wood it exerts a prying force *outward* (see "Ways in which machines help us to do work," pp. 132–133). The force applied to the handle is less than the resistance (the prying force exerted outward by the wedge against the wood), but it travels much farther.

87. †The screw. The spiral[1] staircase is a screw (Fig. 86). You can see that the screw is an inclined plane which winds round and round as it goes up or down. The gentler the slope of the spiral, the less the force the man must exert in raising his weight, but he has to travel much farther in reaching the top. The propeller (Fig. 86, *b*) screws its way through the water, pushing the boat ahead of it.

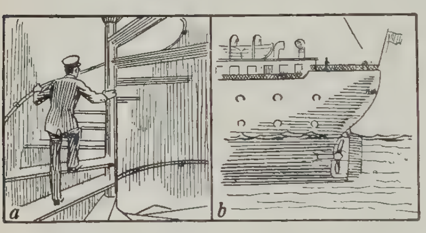

FIG. 86. TWO FAMILIAR EXAMPLES OF THE SCREW

a, the spiral stairway; *b*, the propeller

88. Machines serving in more than one way. Sometimes the same machine may be used in such a way as to illustrate more than one of the six types; for example, when we strike the blade of a hatchet into a block of wood, we are using the hatchet as a wedge; when we pry the blade out of the wood, we are using the hatchet as a lever. Can you illustrate how a garden spade may be used both as a wedge and as a lever?

89. Compound machines. Dozens of machines are used for a variety of purposes about the house and farm. Many of these are merely examples of the six types of

---

[1] *Spiral* (spi′ral): shaped like a curl, or like the path one would make in going round and round a point while getting constantly farther away from the point.

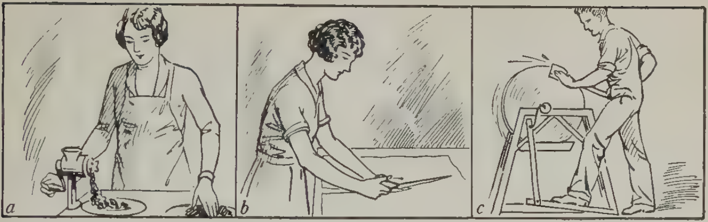

FIG. 87. SOME COMPOUND MACHINES

Explain the fact that the meat-grinder is a screw and a wheel and axle. What two machines are combined in the shears? What two machines are combined in the treadle grindstone? Can you locate the force and the resistance in each of these machines?

simple machines which we have just discussed; many more of them are compound machines made up of two or more simple machines, like those in Fig. 87. Belts and gears (Figs. 88 and 89) are used in many machines.

Special Report. How many simple and compound machines can you find in your home? It will be possible to find at least ten machines besides those named in this chapter, and a careful search may more than double that number.

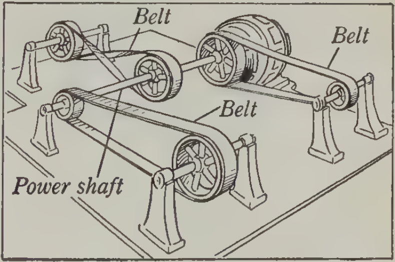

FIG. 88. USES OF BELTS

Belts are used (1) to carry forces to places where they are needed, (2) to change the directions in which pulleys rotate, and (3) to make pulleys rotate slower or faster. Which of the belts in this diagram accomplishes each of these purposes?

90. Labor-saving devices. People often speak of machines as "labor-saving devices," or "devices that save work." Although machines are frequently time-saving

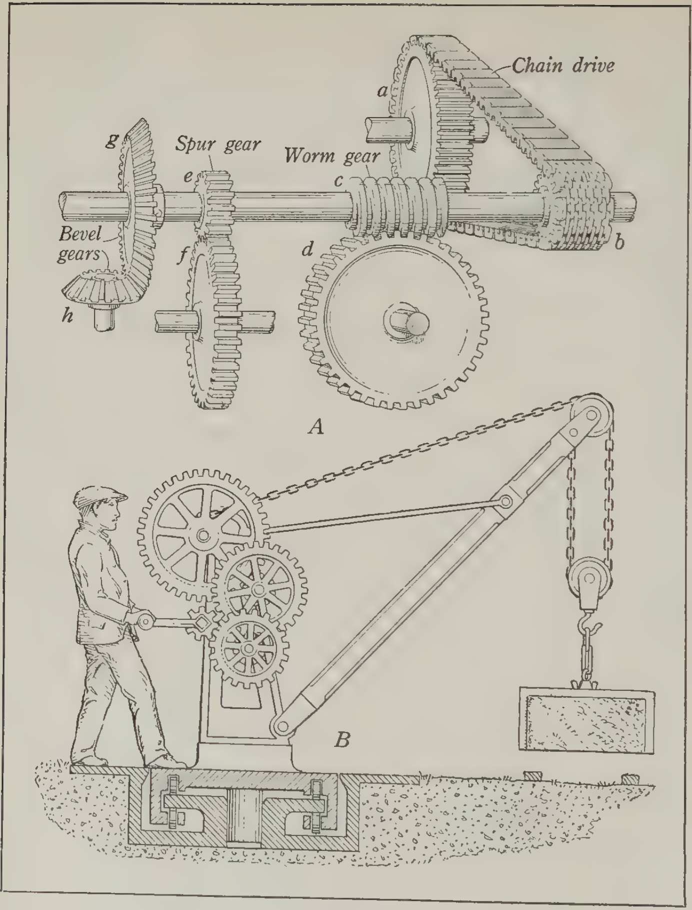

FIG. 89. DIFFERENT TYPES OF GEARS

In *A*, what does each type do that the other types cannot do? What two purposes does the chain drive serve? Do *a*, *b*, *c*, *d*, *e*, *f*, *g*, and *h* turn in the same directions? Does *b* turn faster or slower than *a*? Do *c*, *e*, and *g* and *d*, *f*, and *h* turn faster or slower than *b*? Which of the ways in which machines help us to do work (see pp. 132–133) does the crane in *B* illustrate? Can you find a fixed pulley, a wheel and axle, and a movable pulley? Is the crane a simple machine?

and force-saving, they are never "labor-saving devices" in the sense that they save work; in fact, the total amount of work put into a machine (if we take no account of friction) is always exactly equal to the total amount of work done by the machine. This is called the *principle of work*.

Since there is always friction in every machine, some of the work put into the machine serves no *useful* purpose; it only wears away parts of the machine or moves parts which have become loose. Therefore the total amount of work put into a machine is always greater than the amount of useful work got out of it. Thus, in Fig. 79, p. 136, the total amount of work put into the machines by the man in lifting the box 10 feet is $55 \times 20 = 1100$ foot-pounds. (Remember that his hands moved twice as far as the box.) The useful work done upon the box in lifting it 10 feet is only $80 \times 10 = 800$ foot-pounds.

91. Efficiency. The efficiency of any machine is always found by dividing the useful work got out of the machine by the total amount of work put into it. For example, the efficiency of the pulley system used in raising the box in the problem we have just been considering is 800 divided by $1100 = 0.727$, or 72.7 per cent. The efficiency of any machine is always expressed as a percentage and is always less than 100 per cent. Why?

92. Power is the rate of doing work. If you should run upstairs from the first floor to the second, you would do the same amount of work upon yourself whether you ran up as fast as you could or walked slowly. Although the work done would be the same in both cases, the amount of *power* you would develop would be very different. Power depends upon the amount of time consumed in doing work. The faster work is done, the more power is developed in doing it. The unit of power is horse power, which is

33,000 foot-pounds of work done in one minute, or 550 foot-pounds of work done in a second. Thus, in Fig. 79, p. 136, if the man could raise the box to the level of the window in 2 seconds he would develop 1 horse power (usually spoken of as H. P.), because he would do 550 foot-pounds of work in 1 second, which is 1 H. P. If he required 5 seconds to lift the box, he would be doing only 1100/5 = 220 foot-pounds of work in a second. He would therefore develop only 220/550 = 0.4 H. P. An automobile engine of 40 H. P. can make the automobile go much faster than an engine of 25 H. P., because it can do more work upon the automobile in the same time. It has greater horse power because its rate of doing work is greater.

Experiment 17. How many horse power can *you* develop? Run upstairs as fast as you can while somebody times you accurately to the second. Measure the height of one step and then count the number of steps to find out how many feet you lifted yourself. With this distance and your weight, find the amount of work you did upon yourself. Then find your horse power by dividing the work you did in one second by 550.

93. The metric system a modern method of measurement. Almost all the civilized world except the United States, England, and Russia uses the metric system of weights and measures. It is much more convenient than the system we now use. Our money system is like the metric system in that each unit or measure is one tenth the size of the next larger unit or measure. Thus with our money ten cents make a dime, ten dimes make a dollar, ten dollars make an eagle.

In the metric system likewise each unit is ten times the next smaller unit. The more commonly used metric measures are given in the following tables:

MEASURES OF LENGTH

10 millimeters (mm.) = 1 centimeter (cm.)
10 centimeters = 1 decimeter (dm.)
10 decimeters = 1 meter (m.)
1000 meters = 1 kilometer (km.)
= 0.62 mile

MEASURES OF WEIGHT

10 milligrams (mg.) = 1 centigram (cg.)
10 centigrams = 1 decigram (dg.)
10 decigrams = 1 gram (g.)
1000 grams = 1 kilogram (kg.)
= 2.24 lb.
1000 kilograms = 1 metric ton (M. T.)
= 2240 lb. (the long ton)

MEASURES OF CAPACITY

10 milliliters (ml.) = 1 centiliter (cl.)
10 centiliters = 1 deciliter (dl.)
10 deciliters = 1 liter (l.) = 1.06 quart

Not only scientists but also many people in the United States who are engaged in commerce with foreign countries where the metric system is in use would be glad to see this system adopted in this country; consequently several attempts have been made to establish it by act of Congress as our official system of weights and measures. It is quite possible that before many years we shall,

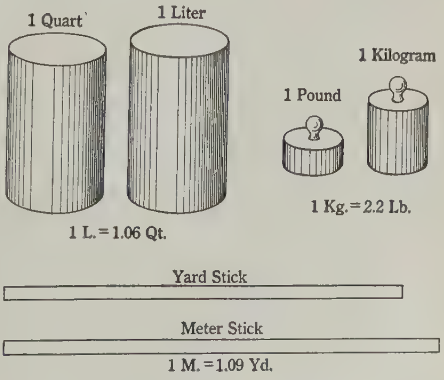

FIG. 90. COMPARING ENGLISH AND METRIC UNITS

like the people on the continent of Europe and elsewhere, be buying milk by the liter instead of by the quart, cloth by the meter instead of by the yard, and meat and groceries by the kilogram instead of by the pound (Fig. 90).

> What changes should you have to make on the dial[1] of an automobile speedometer[2] which registers miles to make it register kilometers? If this country were to adopt the metric system should we have to throw away all our grocers' scales, or should we be able to weigh kilograms, metric tons, etc. with the same scales we now have by changing the balancing weights or the dials of the scales?
>
> *Special Report.* Prepare a discussion of the history, advantages, and uses of the metric system.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. Machines are used to aid us in doing ____.
2. The six types of simple machines are the ____, the ____, the ____, the ____, the ____, and the ____.
3. The seesaw is a simple machine and is an example of the wedge.
4. The simple machine used in raising a flag to the top of a flagpole is the ____.
5. With a fixed pulley the force and the resistance move in the same direction.
6. When the resistance is attached to a movable pulley block, the force is always greater than the resistance.

---

[1] *Dial* (di′al): a circular face marked off for measuring; as, the face of a watch.

[2] *Speedometer* (speed om′e ter): a device for measuring how far and how fast an automobile travels.

7. When the resistance is attached to a movable pulley block, the resistance always moves a greater distance than the force.

8. With a movable pulley the force and the resistance move in opposite directions.

SCIENTIFIC PUZZLES AND GAMES

Can you solve these puzzles on the scientific attitudes in the same way as those on pages 13 and 104?

Problem 1. The head of a prison noticed that every man in the prison serving sentence for stealing had flat and blunt fingers. He concluded that flat and blunt fingers always indicate a tendency to steal.

a. The warden's conclusion was absolutely sound.
b. His conclusion was unsound.
c. His conclusion might be sound but probably was not.
d. His conclusion was probably sound.
e. His conclusion was almost certain to be sound.

Problem 2. This story appeared in a newspaper many years ago: Once Madame Nordica, a very famous singer, was singing at the home of a friend. The guests were on the front porch, since it was a warm summer evening. Shortly after Madame Nordica began to sing, a toad hopped upon the walk close by and remained quietly through her entire song. Other singers of less ability than Madame Nordica followed her. Immediately the toad hopped out of sight and remained hidden while they were singing. But when Madame Nordica sang her second number, to everyone's surprise and amusement the toad again hopped upon the walk and remained in sight again until she had finished her song.

a. It is possible that toads, like some snakes, are charmed by music.
b. The toad just happened to appear during Madame Nordica's second number.

c. The toad appeared again as a tribute to Madame Nordica.

d. Something other than the music attracted the toad during Madame Nordica's songs.

e. It was a different toad which appeared during Madame Nordica's second number.

3. In Fig. 91 and in the legend below it certain problems are presented. Can you solve these problems?

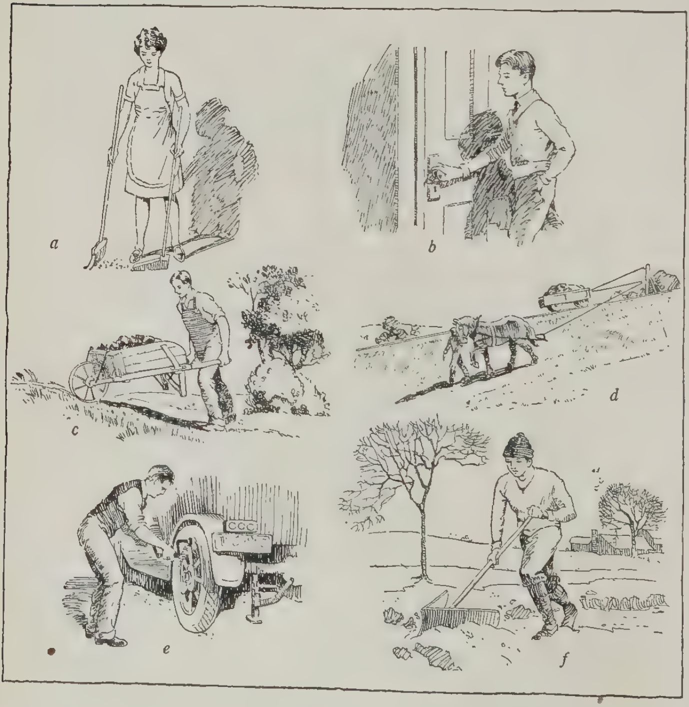

FIG. 91. SOME FAMILIAR COMPOUND MACHINES

a, Find a lever and an inclined plane in this picture; *b*, find a wheel and axle and a lever; *c*, find a lever and an inclined plane; *d*, find three machines; *e*, find two machines; *f*, the machine which the boy is using is ----

UNIT V. UNDERSTANDING AND USING HEAT

CHAPTER XI

RELATIONS OF HEAT AND TEMPERATURE

Some Questions this Chapter Answers

What is the relation of heat to energy? What is the chief source of the earth's heat energy? What is the relation of heat energy to chemical action? to friction? to compression? to electricity? What is the difference between temperature and heat? What is the relation of heat energy to expansion and evaporation? What is the difference between degrees of temperature and calories of heat? How may heat affect the size or state of a body? How are temperatures measured?

94. Heat, a form of energy. Until the beginning of the nineteenth century even the greatest scientists believed that heat was a fluid. They thought that bodies got warm when this fluid (which they called *caloric*) flowed into them and cold when it flowed out of them. They knew that bodies did not get heavier when they became warmer, or lighter when they became colder. Therefore they thought that caloric must be a peculiar fluid which had no weight, and that it could not be matter.

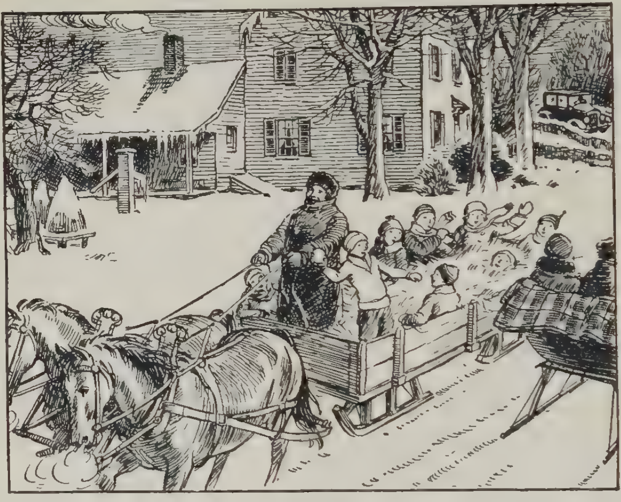

FIG. 92. LOW TEMPERATURES BRING WINTER SPORTS

Have you ever been on a straw-ride party? Burrowed down in the straw with plenty of warm blankets to tuck around you and with enough hot-water bottles or hot bricks to keep Jack Frost at a respectful distance; shouting and singing to an accompaniment of merry sleighbells; dashing along the snowy roads for an hour or so before turning back for a piping-hot supper, which includes many of the foods you most want when you are really hungry!

There are many scientific problems to be found in this picture. Here are four: Why are the straw and the blankets warm as well as soft? Why can you "see" the horses' breath? What made the icicles on the eaves of the farmhouse? What caused the snow to stick to the trees? How many more problems can you find in the picture? Some of these questions and problems you can already answer and explain, and many others you will be able to explain after you have studied the three chapters in this unit.

*In 1799 Sir Humphry Davy found that by rubbing pieces of ice together he could produce enough heat to melt the ice. Thus by transforming mechanical energy into heat he proved that heat is a form of energy and not a fluid. This experiment put an end to the caloric theory.

Heat is now thought to be due to the movement of molecules. The more rapidly the molecules of a body move, the hotter the body is; the more slowly they move, the colder it is. If the molecules of a body cease to move at all, the body is as cold as it can possibly become.

95. †The earth's heat energy. The sun is the earth's most important source of heat energy. Without the sun all the plants and animals on the earth would soon die. Even man, with all his scientific knowledge, could not long survive if the sun were suddenly to stop sending its vast quantities of heat energy out through space.

96. †Chemical action as a source of heat energy. Oxidation is an especially important source of heat energy. When wood decays, it slowly combines with oxygen; that is, it *oxidizes.* When wood burns, it also oxidizes (see page 42). It gives off exactly the same amount of heat when it burns up during a few hours as when it decays during many years. When it decays, however, the heat is produced so slowly that it is not noticed. When it burns, this same amount of heat is produced so rapidly that the wood becomes hot enough to give off light. *Rapid oxidizing, or oxidation which produces noticeable heat and light, is called combustion.* The burning of wood, coal, or other fuels is an example of combustion. Man is able to live in cold climates because he has learned to control combustion. Thus he has a ready supply of heat energy whenever he needs it. Besides oxidation there are many other examples of the transforming of chemical energy into heat energy.

Experiment 18. Can chemical energy be transformed into heat energy when there is no oxidation? Pour a few drops of sulphuric acid into a beaker of cold water (Fig. 93). Feel the bottom of the beaker. Does the temperature of the water change? Is chemical energy transformed into heat energy? Put into another beaker a small amount of lime which has never been exposed to air or water. Cover the top of the beaker with a glass plate, leaving just enough space through which to pour a little water into the beaker. Quickly pour the water into the beaker and immediately cover the beaker with the plate. Feel the bottom of the beaker. Is chemical energy transformed into heat energy?

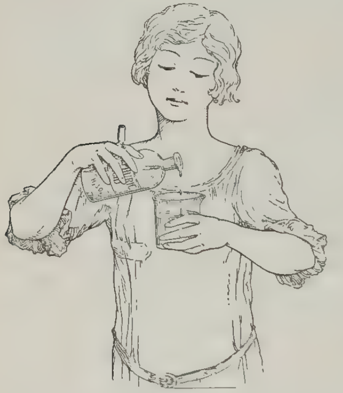

FIG. 93. THIS DIAGRAM SHOWS HOW TO PERFORM EXPERIMENT 18

The girl is illustrating the way in which a chemist holds the stopper while pouring from the bottle. Why is this better practice than to lay the stopper on the table?

97. *Heat energy from friction, compression, and electricity. When you pump up a bicycle tire or an automobile tire with a hand pump or foot pump, the bottom of the piston chamber becomes hot. Part of this heat is caused by friction, but the rest is caused by compressing the air. The high temperatures inside the earth are thought to be caused to a great extent by the compression of the materials of the earth because of gravity (see page 110). Heat energy is also produced by electrical energy. Electric stoves and other electrical heating devices transform electrical energy into heat energy. Heat energy is supplied to the earth by the sun, by friction, by compression, by chemical action (especially oxidation), and by electrical current.

Why are you able to squeeze water out of damp snow when you compress it into a ball?

98. †Expansion and evaporation use heat energy. You are probably familiar with the fact that if you hold your finger in the jet of air as it escapes from the valve of an automobile tire, the air feels cold. The reason is that the air is rapidly expanding. Whenever a body of air is allowed to expand, it becomes cooler. We should expect this to be true from the fact that a body becomes warmer when it is compressed. You are also probably familiar with the fact that wet clothing is much colder than dry clothing, or that your face or hands become cold quickly when they are wet. The reason is that the water is evaporating. Whenever water or other liquids evaporate they become colder.

99. Temperature and heat not the same. We know that a kettle of boiling water will melt more ice than a cup of boiling water will, even though the *temperature* of the water is the same in each. The reason is that the water in the kettle has more heat energy because there is more of it. This fact might be stated in another way: although the molecules are moving equally fast in the kettle and in the cup, the total energy of the molecules in the kettle is greater because there are more of them. We also know that a kettle of *warm* water will melt more ice than a *drop* of *boiling* water. The reason is that the greater amount of water in the kettle more than makes up for the higher temperature of the drop. We might say the same thing in another way: the molecules are moving faster in the drop, but the total energy of all the molecules in the kettle is greater because there are more of them, even though they are moving more slowly.

100. *Degrees of temperature and calories of heat. *A calorie is the quantity of heat energy which must be put into 1 kilogram (see page 145) of water to raise its temperature 1° C.* For example, it would require 1 calorie to raise the temperature of 1 kilogram of water from 20° C. to 21° C., or, stated in another way, 1 calorie of heat would be given off by 1 kilogram of water when it is cooled from 21° C. to 20° C.

How many calories of heat would be necessary to raise the temperature of 10 kilograms of water from 40° C. to 50° C.? How many calories of heat would be given to your hands by 1 kilogram of water if when you immersed[1] your hands in the water you lowered its temperature 2° C.?

It requires more heat to raise the temperature of water a degree than it does to raise the same weight of any other common substance a degree. Thus the number of calories required to raise the temperature of 1 kilogram of water a degree would raise the temperature of 1 kilogram of glass about 5° C., 1 kilogram of iron about 9° C., and 1 kilogram of lead or gold more than 30° C.

Why is a hot-water bottle full of hot water a better foot warmer than a hot iron of about the same weight, even though the iron may be somewhat hotter to begin with?

---

[1] *Immerse* (im mers′): to put an object entirely within a liquid or a gas.

101. *The size of a body changed by heat. Does a body expand (become larger) or contract (become smaller) when it gets hotter?

Experiment 19. Secure a soft-iron bolt and a washer which will barely slip over the bolt. Heat the bolt and see whether it will still pass through the washer. Cool the bolt by dipping it into cold water. Will it pass through the washer now? Summarize the results of this experiment by putting the word "expanded" or "contracted" into the blanks in the following sentence:

> The solid body (the bolt) ____ when it was heated and ____ when it was cooled.

Experiment 20. Set up apparatus as in Fig. 94. Fill the flask so full that when you insert the rubber stopper the water will rise a little way in the tube. Tie a string round the tube on a level with the water in the tube. Heat the water in the flask. After you have heated the flask for a few moments tie another string round the tube to indicate the water level. Pour cold water over the outside of the flask to cool it. Again note the level of water in the tube. Summarize the results of this experiment by putting the word "expanded" or "contracted" in the blanks in the following sentence:

> The liquid body (the water in the flask) ____ when it was heated and ____ when it was cooled.

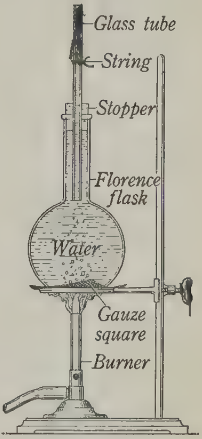

FIG. 94. EXPERIMENTING WITH HEAT

How does water behave when heated and cooled?

Experiment 21. Does a body of air expand or contract when it is heated? Set up apparatus as in Fig. 95. Be sure that the inverted glass is entirely full of water. Heat the body of air in the flask. What happens? Do you have more than a flask full of air when the flask is heated, or less? After heating the flask for perhaps half a minute, remove the burner. What happens? Do you have more than a flask full of air when the flask is cooled, or less? This experiment may also be performed as follows:

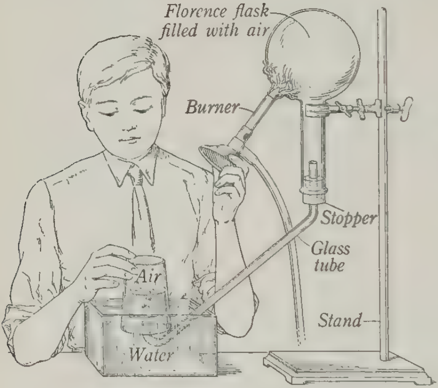

FIG. 95. HEATING A BODY OF AIR

How does air behave when heated and cooled?

Experiment 22. Put an inflated rubber balloon or a rubber ball in a very cold place and leave it for about ten minutes. Observe the size of the object when it has been cooled. Then put it in a warm place long enough for it to become warm but not hot enough to burn the rubber. Summarize the results of these two experiments by putting the word "expanded" or "contracted" in the blanks in the following sentence:

> The body of air ____ when it was heated and ____ when it was cooled.

102. †Heat may change the state of a body. We know that matter exists in three states: solid, liquid, or gaseous (see page 107). If exactly the proper conditions can be secured, a substance can be changed from a solid (as ice) to a liquid (as water) and from a liquid to a gas or vapor (as steam) by heating it. Similarly, a substance can be changed from a gas (as steam) to a liquid (as water) and from a liquid to a solid (as ice) by cooling it. The chemical compound (in this case, water) does not change when the substance changes from one state to another. The molecules of the substance are the same whether the substance is frozen or melted or evaporated.

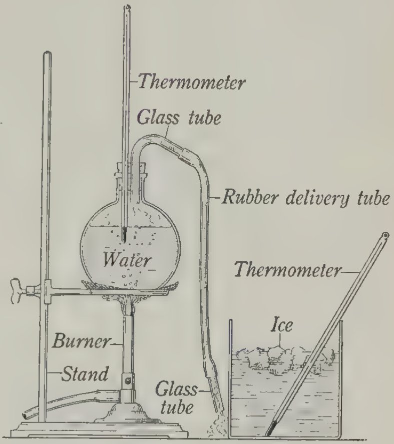

FIG. 96. EXPERIMENTING WITH TEMPERATURES

†Substances such as lard and tar change their state gradually with changes of temperature. That is to say, the colder they are, the harder they are; the warmer they are, the softer they are. Other substances, like water and the metals, have each a certain temperature at which they change from one state to another; that is, from a solid to a liquid or from a liquid to a gas. This certain temperature never varies for a given substance of this kind provided the air pressure does not change.

Experiment 23. Does water change temperature while it is boiling? while ice is melting in it? while steam is condensing in it? Set up apparatus as in Fig. 96. Stir ice in the beaker until the water remains at constant (unchanging) temperature. Light the burner. Note the temperature when the water begins to boil in the flask and continue to note it while the water continues to boil. After the steam begins to come freely from the end of the tube, insert the tube in the beaker containing the ice and water. Stir with the thermometer while the ice is melting. Does the steam continue to rise through the ice water? What happens to it? Does the water in the beaker change its temperature while the ice is melting? Does it change its temperature after the ice is all melted? Make complete sentences answering the three questions asked at the beginning of this experiment.

Special Reports. Make diagrams of and describe the structure and operation of a pressure cooker. Describe the processes of evaporating sap in making maple sirup and sugar.

103. Measuring temperature. When you are walking along the street the first friend you meet is likely to say, "It's cool today, isn't it?" and the next friend you meet is just as likely to remark, "Aren't you glad it is warm today after all our cool weather?" You may smile because just before leaving home you looked at the thermometer and observed that the temperature was the same today as it was yesterday at the same time. Your friends' observations were not scientific, but yours were. Why?

In the autumn we often have what we call a cool day, when the lowest temperature may be 50° F. If we have a day with this same temperature in the middle of the winter, however, we think of it as a decidedly warm day. A cool breeze merely means a current of air cooler than the air to which we have been accustomed. Cold or warm currents of air may occur on any day of the year, whether in winter or in summer.

Experiment 24. Why are thermometers necessary for measuring temperatures? Heat water until it is comfortably warm to the touch. Fill two pans of the same size with this warm water. The water will then be at almost exactly the same temperature in both pans. Hold one hand in cold water for two minutes and hold the other hand for the same length of time in water much warmer than that in the two pans. Quickly put one hand in each pan of water. Does the water *feel* as if it were at the same temperature in both pans? Why do scientists prefer to use thermometers in measuring temperatures?

When a physician wants to determine whether you have a fever or not, why does he put a small thermometer into your mouth instead of deciding by merely putting his hand on your forehead or by asking you whether you think you have fever?

*Ordinary thermometers are glass tubes containing either mercury or alcohol colored red or blue. Above the mercury or alcohol in the tube is a vacuum. When the temperature is raised, the liquid expands toward the top of the tube; when the temperature is lowered, the liquid contracts. Alcohol and mercury are convenient substances to use in thermometers because neither freezes at ordinary temperatures. Experiment 20, p. 155, illustrates the principle of the thermometer.

Arctic explorers cannot use mercury thermometers. Why? Why is the alcohol in thermometers colored?

Special Reports. Find out what kinds of thermometers are used in very cold regions. What kinds are used for measuring very high and very low temperatures in scientific work? Describe the earliest types of thermometers. How many different types of Fahrenheit thermometers can be found in the modern home?

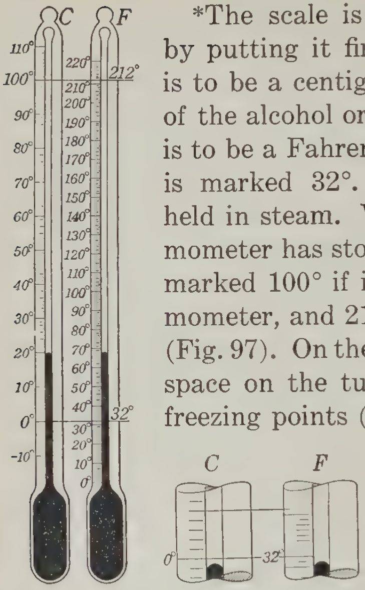

FIG. 97. READINGS ON DIFFERENT THERMOMETERS

Five centigrade degrees occupy the same space on a thermometer as nine Fahrenheit degrees. Therefore, 1° C. = $\frac{9}{5}$° F. and 1° F. = $\frac{5}{9}$° C.

*The scale is marked on a thermometer by putting it first into melting snow. If it is to be a centigrade thermometer, the level of the alcohol or mercury is marked 0°; if it is to be a Fahrenheit thermometer, the level is marked 32°. The thermometer is then held in steam. When the liquid in the thermometer has stopped expanding, the level is marked 100° if it is to be a centigrade thermometer, and 212° if it is to be a Fahrenheit (Fig. 97). On the centigrade thermometer the space on the tube between the boiling and freezing points (that is, the boiling or freezing temperatures) of water is divided into 100 equal parts. Each of these parts represents a centigrade degree of temperature. The space on the tube between the boiling and freezing points on the Fahrenheit thermometer is divided into 180 equal parts, each of which represents a Fahrenheit degree of temperature. Degrees are also marked on the thermometer above the boiling point and below the freezing point. Why?

Fig. 98 is a graph showing centigrade and Fahrenheit temperatures. This graph enables you to change centigrade to Fahrenheit temperatures or Fahrenheit to centigrade temperatures without doing any arithmetic. To find the centigrade temperature which equals any given Fahrenheit temperature, say 140° F., find 140° on the

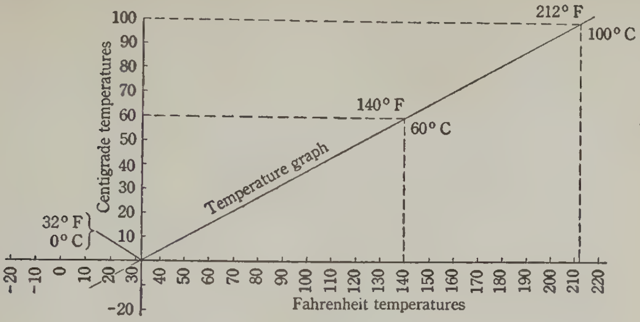

FIG. 98. A TEMPERATURE GRAPH

Can you use this graph?

Fahrenheit temperature line. Find the point directly above 140° F. on the slanting line, then find the point on the centigrade temperature line exactly *opposite* the point on the slanting line. This point is at 60° C. Read off on the graph the Fahrenheit temperature corresponding to 20° C.; the centigrade temperature corresponding to 50° F.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. Heat is a form of ----.
2. Five sources of heat energy on the earth are the sun, ----, ----, chemical ----, especially ----, and electrical ----.
3. It requires 10 kilograms of heat to raise 1 calorie of water 10° C.
4. Degrees are used to measure the ---- of a body; ---- are used to measure the heat that a body contains.

5. When a metal ball is heated, it becomes smaller than when it was cold.
6. A rubber ball filled with air is slightly larger in summer than in winter.
7. Above the mercury or alcohol in a thermometer is compressed air.
8. Five degrees on a centigrade thermometer occupy the same space as ____ degrees on a Fahrenheit thermometer of the same size.
9. The Fahrenheit thermometer is more convenient than the centigrade.

CHAPTER XII

HOW HEAT IS DISTRIBUTED

Some Questions this Chapter Answers

What are the differences between transferring heat by radiation, by convection, and by conduction? What is the relation of convection to winds? What is the relation of convection to the home refrigerator? How is artificial ice made? What is the relation between convection and ventilation? What is the relation between conduction and the freezing of ice cream? Why do things continue to cook in a fireless cooker? What is the relation of clothing to radiation? to convection? to conduction?

104. Transferring heat from place to place. When our hands are cold we know several ways of warming them. If we are out of doors we may put them in our pockets to prevent them from losing their heat, we may rub them vigorously[1] together, we may blow our warm breath upon them, or we may exercise our arms and hands in various ways to make the blood circulate more rapidly.

*If we are indoors we hold our hands in front of the fireplace or electric heater, over the hot-air register or radiator, or against some warm object which is not too warm for comfort. Thus we use the three ways in which heat energy is transferred from one place to another; namely, *radiation*, *convection*, and *conduction*.

---

[1] *Vigorously* (vig′ẽr us ly): actively and with force.

105. Radiation. *Experiment 25.* In what directions does heat radiate from a hot body? Heat a metal object, such as a very large iron nail or the end of an iron poker. When it is red-hot, hold it above and very close to a block of paraffin (do not let it touch the paraffin). Does the heat travel downward from the hot iron to the paraffin? Again heat the iron and hold it close beside the paraffin. Does the heat travel horizontally from the hot body? Repeat, holding the iron just below the paraffin. Does the heat travel upward from the hot body?

Summarize the results of this experiment by giving the following statement the correct ending, choosing it among the five endings given: This experiment indicates that heat travels by radiation **only horizontally** **only vertically**[1] **in all directions** **only horizontally and vertically** **in all directions except downward.**

*Heat travels by radiation; that is, it radiates in straight lines from the hot body. It does not travel on matter, but is able to pass in waves through a vacuum with a speed of about 186,300 miles per second.

*All the heat which comes to us from the sun travels by radiation. During the night and the winter the earth radiates away much of the heat which it receives by radiation from the sun during the day and the summer. If it did not do this, the earth would gradually become hotter and hotter until nothing could live upon it.

Radiant, or radiated, heat waves pass through the millions of miles of almost perfect vacuum between the sun and the earth without heating the space at all. When radiant heat strikes matter, it raises the temperature of the matter (Fig. 99); that is, the radiant heat makes the molecules move faster. There are some substances, however, which are almost transparent[1] to radiant heat; that is, they stop and absorb only a small part of the waves which radiate through them. Thus objects in the sunlight inside a room are warmer than the window glass through which the sun's rays pass.

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[1] *Vertical* (ver′ti kl): straight up and down; the opposite of horizontal.

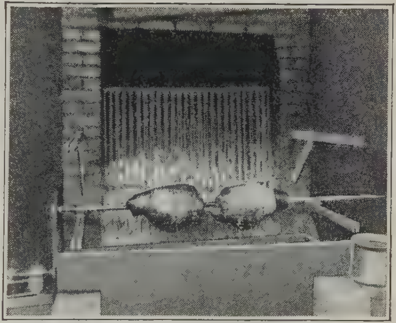

FIG. 99. COOKING MEAT BY RADIATION

Rough surfaces absorb radiant heat better than smooth and polished surfaces, and smooth and polished surfaces reflect radiant heat better than rough surfaces. Objects with rough surfaces radiate their heat away faster than objects with smooth surfaces. Dark-colored objects absorb radiant heat faster than light-colored objects do.

> Why is the reflector on an electric heater made of smooth, polished metal? Why are the surfaces of steam radiators rough rather than smooth and polished?

Experiment 26. How can we find out whether a light-colored surface or a dark-colored one absorbs radiant heat better? Place on snow or on a cake of ice in the sunlight two flat pieces of tin of the same size and shape, one painted white and the other black. After ten minutes, which has melted the more snow or ice? State in a complete sentence whether a light-colored surface or a dark-colored one absorbs radiant heat better.

---

[1] *Transparent* (trans pair′ent): allowing sunshine to pass through.

106. Convection. *Experiment 27.* How does heat travel from one place to another by convection? Put some fine, wet sawdust or some small bits of lead from an indelible pencil into a beaker of water so that some of it is at the bottom of the beaker. Light a burner under one edge of the beaker. As the water becomes heated do the bits of sawdust or pencil lead move in straight lines or in curving lines?

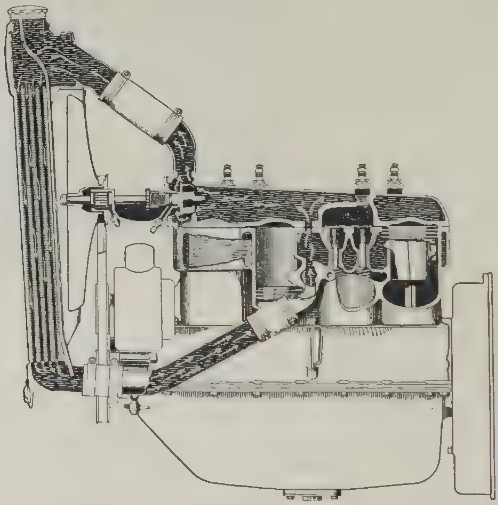

FIG. 100. CONVECTION CURRENTS IN THE COOLING SYSTEM OF A FOUR-CYLINDER AUTOMOBILE ENGINE

The water absorbs heat from the engine. Why does the water circulate in the direction of the arrows? Why is water the best liquid to use for this purpose? (By courtesy of the Ford Motor Company)

*Heat travels by convection in currents (Fig. 100). When air or water becomes heated, it expands and becomes less dense (see page 110) than the colder air or water round it. The warm air or water is then forced upward for the same reason that a bubble or a cork which is released beneath the surface of water is pushed up to the surface — because it is less dense than the water round it (Fig. 101).

What part of Fig. 101 is like a part of Fig. 100. Explain why the products of combustion escape through the chimney from the heater. Why is the heating coil (Fig. 101) spiral instead of straight? Why is not the cold water admitted at the top of the tank?

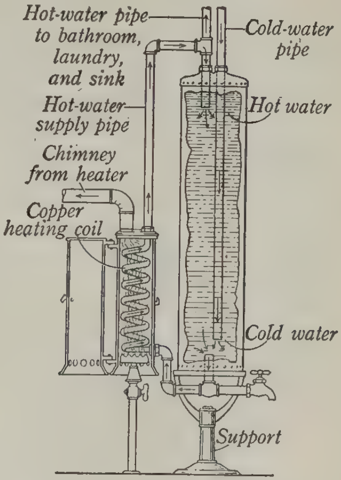

FIG. 101. HOT-WATER BOILER

Why does the water circulate in the direction of the arrows?

107. Conduction. Heat travels by conduction from molecule to molecule. We are familiar with the fact that when one end of an iron poker is held in the fire, the heat energy travels along the poker to the hand. Scientists explain how the heat is conducted along the poker, in this way: The iron in the fire has its temperature raised; that is, the speed with which its molecules vibrate[1] has been increased. These faster-moving molecules hit against the molecules next to them in the poker, making them also vibrate faster; these in turn strike against molecules farther away, causing them to vibrate faster; and so on.

---

[1] *Vibrate* (vi′brate): to move to and fro, as the wings of a buzzing bee. A house vibrates when a heavy truck goes by. *Vibration* (vi bra′shun): the act of vibrating.

*Some substances are good conductors of heat; others are not. The metals are better conductors of heat than other substances. Solids in general conduct heat better than liquids, and liquids conduct heat better than gases. Silver is the best heat conductor known.

Why are wooden handles put on metal coffeepots?

Experiment 28. Is water a good conductor of heat? Fill a test tube with water. Dry the outside thoroughly, then hold the tube in the flame, as in Fig. 102, until the water boils above the flame. Make a complete sentence that answers the question at the beginning of this experiment, giving a reason for your answer.

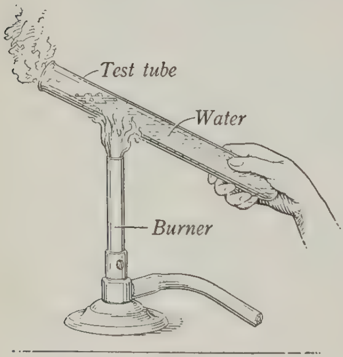

FIG. 102. DIAGRAM ILLUSTRATING CONDUCTION IN WATER

Would it be comfortable to hold the test tube if the hand and the burner were to exchange places? Explain

108. *Summary of important differences. Heat travels by radiation in waves without the help of matter; it travels by convection and conduction only by means of matter. Radiant heat travels at enormous speed in straight lines and in any direction as readily as in any other; heat carried by conduction or convection travels slowly compared with radiant heat and often in curving routes. Convection currents are set in motion by gravity. Convection takes place only in liquids and gases; conduction takes place mostly in solids, very little in liquids, and almost not at all in gases. Heat is conducted when rapidly moving molecules strike against other molecules which are moving more slowly. Heat is carried by convection when an enormous number of rapidly moving molecules travel together. It will help you to get a better idea of convection if you think of a moving swarm of insects. Each has its own speed and direction within the swarm, but all are moving in the same general direction.

109. All winds and air currents caused by convection. *Experiment 29.* How do air currents move near a lighted candle? Prepare a pasteboard box in the manner indicated in Fig. 103. Place a candle in the box. Put on the cover. Hold any smoking substance near each hole in the box. Does the smoke enter either hole? Light the candle and put on the cover. Again hold the smoking substance near each hole in the box. Does the smoke enter either hole? Was the smoke pushed into the box or drawn into it? Explain. Was the warm air above the flame pushed upward or downward?

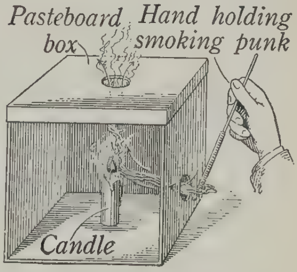

FIG. 103. DIAGRAM OF A SIMPLE CONVECTION BOX

†The convection currents of air move through the box for the same reason that they move through the cooling system of the automobile and through the water tank (Figs. 100 and 101). When the candle is lighted, the air immediately above the candle becomes heated and consequently expands. When it expands, some of it escapes from the box, forming a partial vacuum above the candle. The greater pressure of the denser cold air outside the box forces air into the partial vacuum above the flame, causing currents to flow upward through the box.

†Winds are caused in the same way. The surface of the earth heats unequally (1) because the sun's rays strike some surfaces more directly than others and consequently heat them faster, (2) because some surfaces are smoother than others, and (3) because some substances heat faster than others (see page 154). The air heats faster above the warmer areas than it does above the colder areas. The greater pressure of the denser air over the colder areas then forces colder air toward the partial vacuum over the warmer areas, causing winds. The air currents above the warmer areas are moving upward just as the air was pushed upward above the lighted candle in Experiment 29.

*For many centuries man has been using the mechanical energy of wind to drive boats with sails; in fact, even as late as the beginning of the nineteenth century practically all ocean commerce depended upon the wind. Much of the commerce of the world is still carried in sailing ships. For centuries too the kinetic energy of wind has been used to drive windmills for pumping water and for grinding grain. In a few parts of the earth windmills have recently been used to generate electric current.

110. †The home refrigerator and the principles of convection. Whenever one body touches another, the warmer always gives up heat to the colder. Thus, when ice is put into a refrigerator[1] it takes some heat out of the shelf upon which it rests and more out of the air surrounding the ice. The heat which the ice absorbs melts the ice.

Can you explain the action of the refrigerator (Fig. 104) by selecting the proper word or phrase from each pair

---

[1] *Refrigerate* (re frij'er ate): to make or keep cool substances such as food. *Refrigeration* (re frij er a'shun): the process of refrigerating; *refrigerator:* a box to keep food very cool.

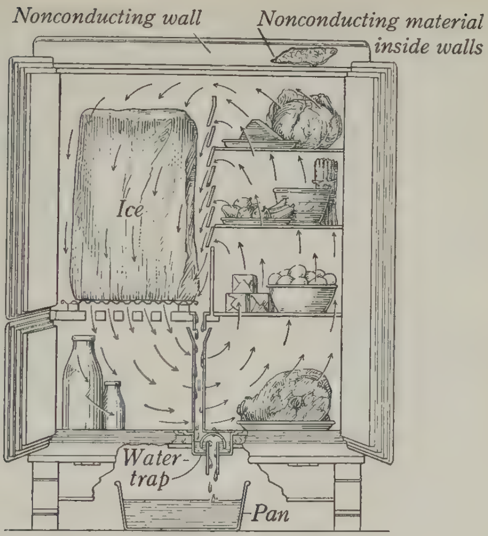

FIG. 104. AN ICE REFRIGERATOR

Explain why the air moves in the direction of the arrows

in the following statements? When the air gives up heat to the ice, it becomes **warmer** **cooler** and contracts. It therefore becomes **heavier** **lighter** than the same volume of warm air in the other parts of the refrigerator. It is then **pushed up** **pulled down** by gravity; and as it falls it pushes up the warm air in the food compartments, making convection currents.

Why not put the ice in the bottom of the refrigerator?

If it were not for the water trap the cold air would fall out with the water from the melted ice. Explain.

A certain woman wanted to save money by making her ice last longer. She therefore wrapped it in several thicknesses of newspaper and an old quilt before she put it into the refrigerator. The ice did melt very slowly (Why?), but she learned after a few days that hers was a very poor way to save money. Explain.

111. *Artificial ice. Fig. 105 shows how artificial ice is made. When the ammonia gas is compressed, it becomes hot (see page 152). The hot ammonia gas is made to pass through pipes round which cold water circulates. The cold water absorbs the heat from the ammonia gas. When the compressed ammonia gas becomes cool enough it condenses into a liquid, just as water vapor condenses into rain when it is cooled sufficiently. The liquid ammonia is allowed to pass through the valve into coils which pass through tanks of brine.[1] In these coils it evaporates rapidly, becoming cooled just as water becomes colder when it evaporates (see page 153). The ammonia gas becomes still colder when it expands in the coils. The very cold ammonia gas absorbs heat from the brine, making the brine colder than the freezing temperature of pure water. Huge cans the size and shape of manufactured ice cakes are filled with pure water and immersed in the cold brine. The water in the cans freezes into cakes in from one to two days.

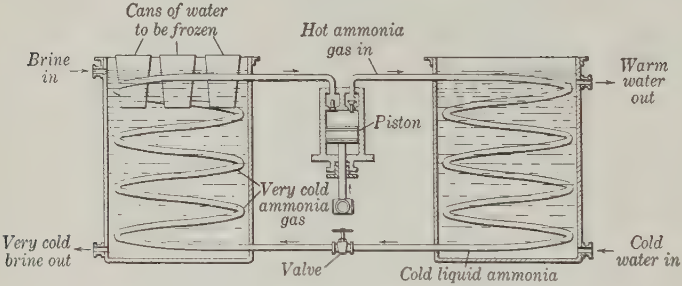

FIG. 105. MAKING ARTIFICIAL ICE

What part of Fig. 105 is like the water jacket of the automobile engine shown in Fig. 100, p. 166?

---

[1] *Brine:* a strong solution of salt in water.

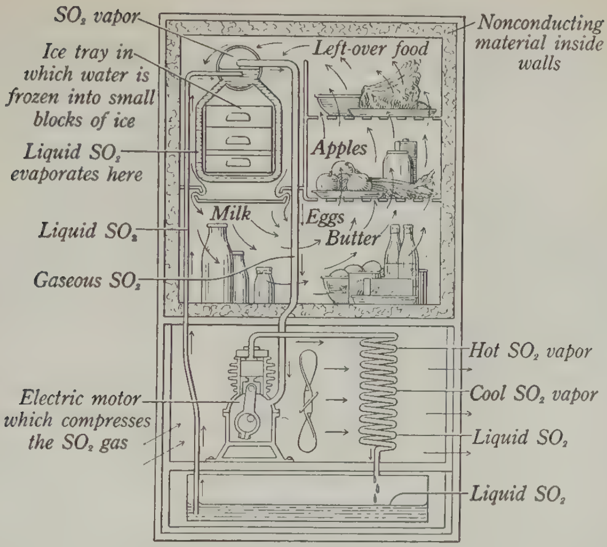
SO₂ vapor
Ice tray in which water is frozen into small blocks of ice
Liquid SO₂ evaporates here
Liquid SO₂
Gaseous SO₂
Electric motor which compresses the SO₂ gas
Noncondncting material inside walls
Left-over food
Apples
Milk
Eggs
Butter
Hot SO₂ vapor
Cool SO₂ vapor
Liquid SO₂
Liquid SO₂

Fig. 106. A Type of Mechanical Refrigerator (Frigidaire)

In cold-storage plants brine which has been cooled in the same way as that just described is pumped through coils in the cold-storage rooms, where it absorbs heat from the air.

> *Special Reports.* Explain the preparation and properties of liquid air. Several of the modern "electric refrigerators" or "iceless refrigerators" are small cold-storage and ice-making plants combined. Sulphur dioxide is commonly used in these machines instead of ammonia, but the process is essentially the same as that used in the manufacture of artificial ice. Fig. 106 is a diagram of one type of "mechanical refrigerator." Can you explain its action?

Very recently solid carbon dioxide ("dry ice") has begun to make its appearance as a substitute for ice in certain types of refrigeration. Gaseous carbon dioxide is first condensed into a liquid in much the same manner as the ammonia in the manufacture of artificial ice. The liquid carbon dioxide is allowed to evaporate very rapidly. The evaporation makes it so cold that it freezes and looks like snow. It is then compressed and cut into blocks of convenient size to be packed round perishable[1] foods for transportation (Fig. 107). Solid carbon dioxide evaporates directly into gaseous carbon dioxide without passing through the liquid state. The carbon dioxide gas thus formed is colder than ice; in fact, carbon dioxide can be made to produce temperatures as low as −109° F., 141 degrees colder than ice.

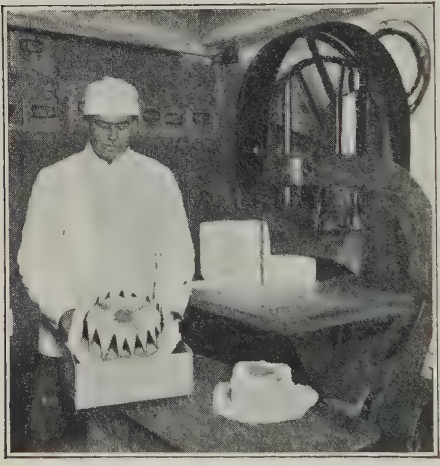

FIG. 107. PACKING AN ICE-CREAM PUDDING IN SOLID CARBON DIOXIDE FOR SHIPMENT

The carbon dioxide is cut with the band saw into pieces of the proper size

Solid carbon dioxide now costs much more per pound than ice; but one pound of solid carbon dioxide can do as much refrigerating as fifteen pounds of ice, and at the same time it is more convenient and desirable for refrigerating perishable foods which are shipped long distances. Solid carbon dioxide is not suitable for use in household refrigerators, but it is probable that in the near future special refrigerators will be designed to use solid carbon dioxide instead of ice.

[1] *Perishable* (per'ish a bl): liable to decay or to be destroyed quickly.

112. *Ventilation by means of convection. Ventilation is provision[1] for a free circulation of air. Primitive[2] man was not concerned with ventilation. His outdoor life provided all the fresh air that he needed. When men learned to build tight houses and to heat them in various ways, they gained in comfort but lost in health because of poor ventilation. Lately people have been giving more attention to securing the proper ventilation of their homes.

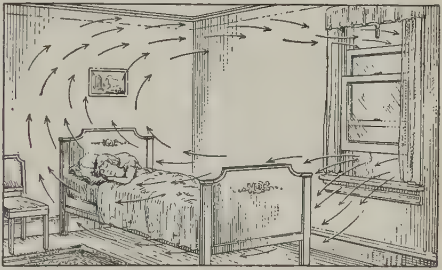

FIG. 108. THE PROPER USE OF WINDOWS IN VENTILATING A ROOM

*Proper ventilation supplies our homes with constantly moving air which is free from unpleasant odors, which has an indoor temperature of from 65° F. to 70° F., and which has enough moisture to be healthful. If sufficient fresh air is constantly being admitted from out of doors, the rooms are likely, in general, to be healthful.

*When the windows are used for ventilation the best results will be obtained if they are opened a little both at the top and at the bottom on the same side of the room (Fig. 108).

Experiment 30. When a window is open both at the top and the bottom, do the convection currents enter at the top and leave at the bottom or enter at the bottom and leave at the top? Open a window a few inches at the top and at the bottom. Hold a lighted candle near the top and the bottom. Note the direction in which the flame is blown by the convection currents. Can you summarize the observations of this experiment by filling the blanks in the following sentence?

---

[1] *Provision* (pro vizh'un): arrangements, care taken to make sure that something is on hand.

[2] *Primitive* (prim'i tiv): at the start, in an early time or the beginning.

> When a window is open both at the top and at the bottom the air currents enter at the ---- of the window and leave at the ----.

From your knowledge of convection should you expect that this statement would be true even though you had not done the experiment? Explain.

113. †Conduction in the freezing of ice cream. Ice and salt are ordinarily used to freeze the cream which is in the can of an ice-cream freezer. The ice alone could not cool the cream enough to freeze it; but the salt dissolves on the wet surface of the ice and causes the ice to melt rapidly, forming a solution of salt in water. This salt solution is much colder than the freezing temperature of water, because (1) some of the heat energy is used in dissolving the salt and (2) much more heat energy is used in melting the ice. The cold salt-water solution absorbs heat from the cream. The tub of the freezer wall is usually made of wood, and wood does not conduct heat readily. The metal of the can is a good heat conductor; therefore the salt solution in the freezer takes most of its heat from the can and its contents.

114. Conduction is diminished in the fireless cooker. The early pioneers in this country sometimes heated a kettle of food to the boiling temperature, then raked the camp fire aside, and, while the food was still boiling, buried the kettle in the dry hot earth. When they returned hours later they found the food thoroughly cooked and still hot. In this cooking they used the principle of the modern fireless cooker.

The fireless cooker consists of a double-walled box (Fig. 109). Mineral wools, straw, or some other nonconducting material is packed loosely between the walls so as to leave as many small air spaces as possible. When a kettle of boiling food is put into the box, the heat is conducted through the walls very slowly, so that the food continues to cook for hours. In some fireless cookers hot irons or soapstone disks are placed above and below the aluminum kettle containing the hot food. The aluminum is a good conductor and conducts the heat to the food, and the walls prevent the rapid loss of heat from the box. In modern electric fireless cookers heating coils inside the cooker start the food cooking.

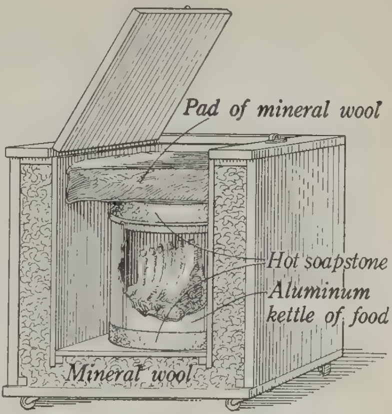

Fig. 109. A Fireless Cooker prevents the Rapid Escape of Heat

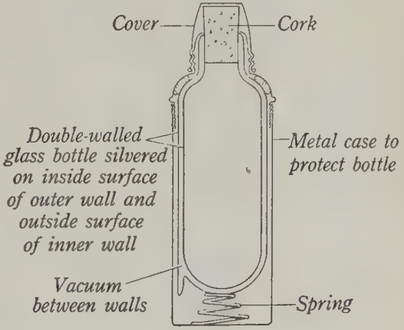
Cover
Cork
Double-walled glass bottle silvered on inside surface of outer wall and outside surface of inner wall
Metal case to protect bottle
Vacuum between walls
Spring

Fig. 110. The Vacuum Bottle prevents Heat from Escaping from Hot Liquids and prevents Heat from Entering Cold Things

Can you explain how radiation and convection assist conduction in cooling the food which is cooking in a fireless cooker?

Special Report. Describe the transfer of heat in the vacuum bottle (Fig. 110).

115. Radiation, convection, and conduction affected by clothing. Primitive man wore no clothing. Without clothing he could live only in warm climates. As man became civilized, however, he found that clothing enabled him to live in colder climates than he could endure without it.

*The first clothing consisted of the skins of animals. After thousands of years man learned to weave cloth out of animal hair, such as wool and camel's hair; out of plant fibers, such as cotton and flax; out of threads produced by silkworms; and recently out of wood (artificial silk).

†We often hear the expression "warm clothing." Clothing, however, is neither warm nor cold. It cannot give heat to the body; it can merely help the body to conserve[1] the heat which the body secures mostly from the oxidation of the food we eat. In winter, when the air is much colder than the body, we must prevent the body from losing its heat too rapidly to the air. We must diminish the radiation, convection, and conduction of heat away from the body. Then, too, the body gives off about half a gallon of water a day in the form of perspiration. We must prevent too rapid evaporation of this perspiration from the skin in winter, since much heat is always used up in evaporating a liquid (see page 153).

†Clothing breaks up air spaces round the body and hence diminishes convection from the body; it also stops

---

[1] *Conserve* (kon serv′): to consume in sensible ways and without waste. *Conservation* (kon ser va′shun): the act of conserving.

considerable radiation from the body. If we wore no clothes we should lose little heat by conduction, because air is a very poor conductor of heat. Some kinds of clothing materials conduct heat readily; therefore in winter our problem is to use clothing that does not do this.

†It is easier to prevent conduction of heat away from the body in winter by wearing several thin garments than by wearing the same weight of clothing in one garment, because of the thin layers of air between the garments. The more air spaces cloth contains in its weave, the less readily it conducts heat; hence wool is better than either cotton or silk for winter wear because it can be woven more loosely and because it can be woven with a nap which makes still more air spaces. Wool is best for winter wear also because it absorbs moisture, such as perspiration, very much more slowly than other kinds of cloth and also evaporates it very much more slowly.

†All-wool material is not satisfactory for inner garments, because it is not comfortable to the skin and because it is likely to shrink when washed, thereby closing the air spaces. The best garments to wear next to the skin in winter are a mixture of silk and wool, and the second best are a mixture of cotton and wool.

†In summer our problem is not to conserve the body heat but to get rid of it. The qualities which make cotton, silk, and linen less desirable for winter wear make them more desirable for summer wear. These substances are also better than wool because they remove perspiration more readily. Linen outer garments especially are excellent for summer wear, because linen absorbs and evaporates moisture more rapidly than any other kind of cloth. White and green are better summer colors than black, red, or orange because they reflect more of the sun's

radiant heat and absorb less of it. It is important, however, that summer clothing allow certain of the sun's rays, which are especially necessary to health, to penetrate readily to the body. It is claimed that artificial silk is more transparent to these rays than the other materials, though cotton and silk clothing also permit considerable proportions of the rays to pass through.

Experiment 31. How do various cloth fibers differ from each other? With a strong hand lens or a microscope examine the fibers of wool, silk, linen, cotton, and artificial silk. Make drawings showing the differences which you observe.

The fur of animals contains more air spaces than the most loosely woven cloth. It is estimated that the fur of some animals contains more than 95 per cent of air and less than 5 per cent of hair. Why is fur such excellent clothing for severe winter weather? Is fur clothing sensible for summer wear? Why? Why do birds during cold weather keep warm by making their feathers stand out from their bodies instead of letting them lie smooth?

116. †Manufacture of clothing. Most of the cloth used in this country is made of the fibers around the seeds of the cotton plant. Woolen cloth ranks next to cotton in the quantity used, silk comes next, and linen, which is made of the fibers from the stems of flax plants, next.

†The first step in the manufacture of cloth is to make the thread. Plant fibers or strands of wool are twisted together into thread of various sizes. Silk thread is made by dropping the cocoons[1] of the silkworm into boiling water to kill the animal inside, then winding upon reels the

---

[1] *Cocoon* (ko koon′) : the case which a silkworm spins in which to live while developing into a silk moth.

strands of silk of which the cocoon is made. These separate silk strands are later twisted together into thread.

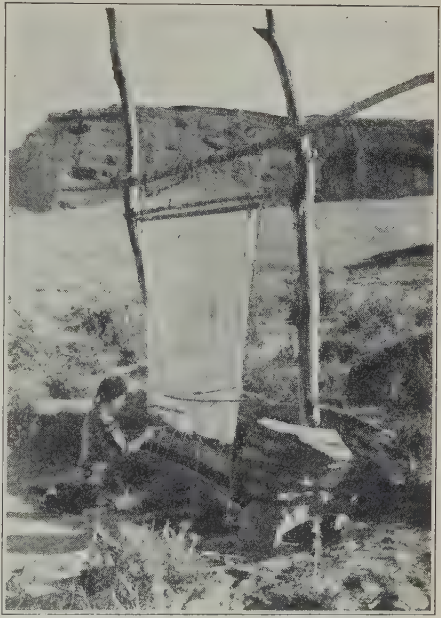

FIG. 111. A NAVAJO INDIAN WOMAN WEAVING CLOTH IN ARIZONA

The Indians were skillful in making cloth to protect them from losing heat from their bodies. (Photograph by George R. King)

†Cloth is made by weaving thread upon looms. In ancient times all weaving was slowly done by hand on looms which were merely rude wooden frames. Coarse threads were first stretched across the loom in one direction, then smaller threads were woven in the other direction over and under the coarse threads. Some weaving is still done by hand among primitive peoples (Fig. 111), but most of the cloth used in the world now is made by machinery.

Special Reports. What tests may one use to determine the various kinds of fibers in cloth? How do cloths made from different fibers differ from each other? For what purposes is each material best suited? What mixtures of fibers are common in clothing? How are artificial silk, muslin, mercerized cotton, and other special kinds of cloth made? What is "shoddy"?

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. Heat is transferred from one place to another in three ways: by ----, ----, and ----.
2. Heat travels by convection in straight lines.
3. Heat comes to the earth from the sun by conduction only.
4. When one puts one's hands in warm water the hands are warmed by conduction.
5. When meat is broiled by putting it *below* the flame, it is cooked by convection.
6. Wind possesses potential energy, which is used in doing useful work.
7. An evaporating liquid becomes warmer.
8. Water is frozen **by adding cold to it** **by putting salt into it** **by adding ammonia to it** **by taking heat from it** **by suddenly raising its temperature.**
9. Ventilation is made possible by radiation.
10. Healthful indoor air must not only be about 68° F. but must also contain considerable amounts of ---- vapor.

CHAPTER XIII

FIRE AND HEATING IN HOME AND COMMUNITY

Some Questions this Chapter Answers

How do heat and combustion depend upon oxygen? What is a match? How does a match produce fire? How were homes heated before the present century? What are the advantages and disadvantages of heating with a fireplace? How does the modern stove operate? How is the home heated by the pipeless furnace? by the hot-air furnace? by the hot-water system? by the steam heating system? What are the relative advantages of hot-air heating? hot-water heating? steam heating? What is the purpose of a chimney? How is heat conserved in the home? What are the common types of fuels and their uses? How is coal gas made? How is the gas meter read? How is dyeing done? How is charcoal made? What are the products of combustion? How may fire be both a friend and an enemy? How are fires extinguished? How are destructive fires started? How may they be prevented?

117. Oxygen and heat needed for combustion. When we cause combustion by burning wood, coal, or other fuels we say we have made a fire. Such combustion is accompanied by flame. Nobody yet knows what flame is. We only know that flame is a phenomenon which accompanies fire.

Special Reports. Prepare a discussion of the discovery of fire; fire worship; superstitions concerning fire; the relation of the use of fire to the advances in civilization. What is the proper way to start a camp fire?

Project. To make a fire by primitive means. From a Boy Scout manual find out how to kindle a fire by whirling the sharp point of a stick of hard wood against a piece of dry soft wood. Also see whether you can kindle a fire by striking a spark by means of flint and steel into an old soft cotton cloth.

*Fire will not burn (that is, this kind of combustion will not take place) unless oxygen is present. We therefore pile the wood or coal loosely so that the air can pass through the fuel, bringing fresh supplies of oxygen (see page 42) as they are needed for the combustion. If the fuel is not piled loosely the fire goes out, because there is not enough oxygen for combustion.

Why is a stove or a furnace grate well supplied with openings?

*We know that the fire in the fireplace, furnace, or stove never starts just because the fuel is piled loosely and because there is plenty of draft. Cold wood will not burn, neither will cold coal. The fuel must become heated before it will burn. As soon as part of it becomes hot enough to burn, the heat given off by this combustion heats the rest until it also is hot enough to burn. Why do we start fires with paper and small pieces of wood?

Why does the flame creep slowly along a burning match instead of covering the whole match as soon as it is lighted?

*Every substance must be heated to a certain temperature before it will burn. The temperature at which the

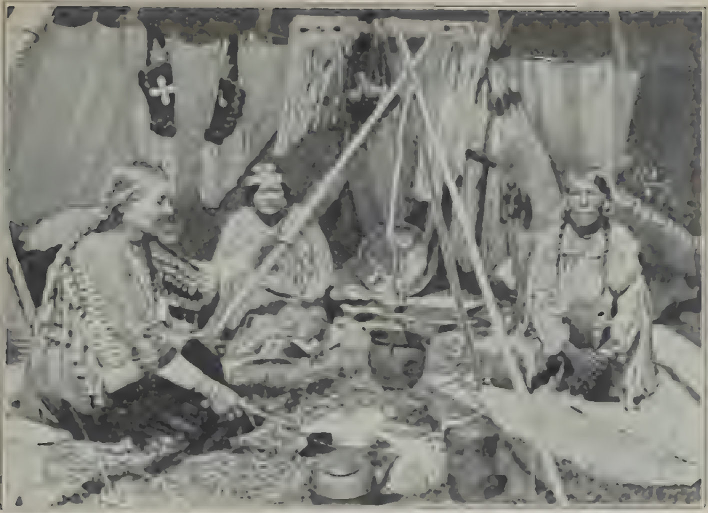

FIG. 112. AN INDIAN HOME, GLACIER NATIONAL PARK

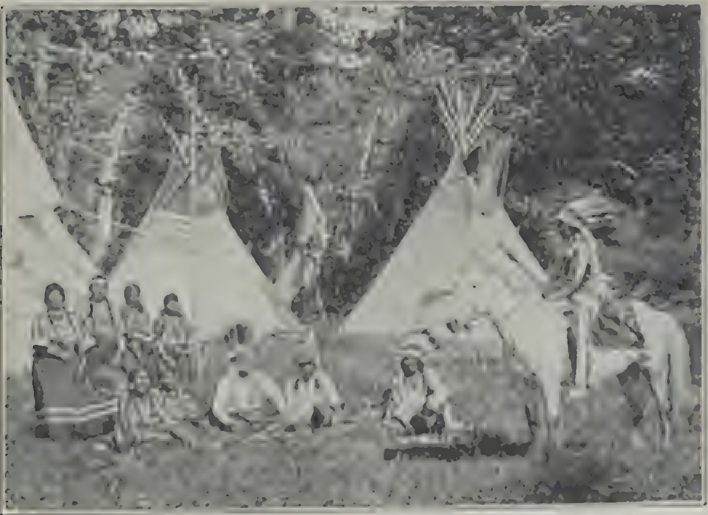

FIG. 113. BLACKFOOT INDIAN CAMP, ST. MARY'S LAKE
How did the Indians solve the fire-and-smoke problem?

substance begins to burn is called the *kindling temperature* (or the *kindling point*) of the substance. When a candle is lighted, the wick[1] is first raised to the kindling temperature. It begins to burn and to produce heat rapidly. The heat first melts some of the paraffin, then changes the liquid paraffin to a vapor. When the paraffin vapor becomes heated to its kindling point, it begins to burn. Some substances have a low kindling temperature; that is, combustion begins when these substances are at a relatively low temperature. Loose paper is such a substance and is a good material with which to start fires because it has a low kindling temperature. Hard coal has a much higher kindling temperature. Iron has a still higher kindling temperature. (See page 42.)

118. Matches a recent invention. In colonial and pioneer days there were no matches such as we now have for kindling fires. Kindling a fire then was no easy task. The pioneer family therefore tried to keep the fire burning constantly. If it went out, live coals with which to start another fire were carried from another pioneer home, or a new fire was kindled with flint and steel. Sometimes cloth put in the fireplace was set on fire by firing into it a gun loaded with powder but no bullet.

*One type of the common friction match is made by first dipping the ends of small sticks into melted paraffin. The ends with the paraffin are then dipped into a paste made of a compound of phosphorus, some oxidizing substance, such as manganese dioxide or potassium chlorate (Experiment 4, p. 41), and glue. When the head of the match is rubbed against any rough substance, the heat caused by the friction raises the phosphorus compound to its kindling point, the heat from the burning compound raises the paraffin to its kindling point, and heat from the burning paraffin in turn raises the wood to its kindling point. Sometimes powdered glass is added with the glue to increase the friction. The oxidizing material supplies oxygen to increase the combustion. The glue sticks the various chemicals together and at the same time protects the phosphorus compound from the oxygen in the air, which would slowly oxidize it.

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[1] *Wick*: a string or woven strip used in a candle or an oil lamp.

Friction matches are liable to be ignited (that is, set on fire) by accident; therefore in some places safety matches are required by law. These matches contain some of the necessary substances on the head of the match; the rest is in a thin layer on the side of the box. If the head of the match is rubbed against a rough surface, the head is rubbed off without lighting the match; if it is rubbed against the substances on the side of the match box, the friction sets the match on fire in much the same way that the friction match is ignited.

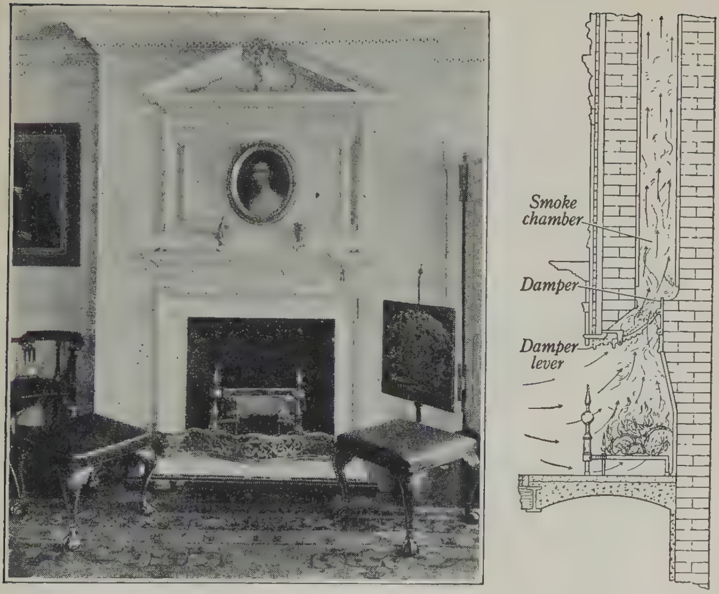
119. *Early attempts to heat the home. Primitive man lived in caves when he could find suitable ones for habitation. These caves were never very cold. They had the further advantage of remaining at about the same temperature all the year round. When, after thousands of years, man learned to use fire, he began to heat his caves and rude huts with open fires. The smoke which was carried along with the convection currents was doubtless very annoying. He had to accept the smoke, however, in order to get the heat. No man had then learned what every high-school pupil may now easily learn.

*After many centuries of development man learned, either by chance or by experiment, that if he left a hole in the roof of his rude dwelling most of the smoke would escape through the hole (Fig. 113, p. 185). Of course there was still too much smoke for comfort in the early days of the smoke hole in the roof. The Romans tried to avoid the disadvantages of open fires in their houses. They built a compartment beneath the floor through which passed hot gases from the fire. These gases heated the floors of the rooms above by conduction.

*The fireplace, built into the wall with a chimney outside, marked a great forward step in the heating of houses. It furnished the idea which after many centuries led to the invention of our modern stove and hot-air furnace.

> The Multnomah Indians of Oregon hit upon the idea of building a fire in the middle of a large circular pit made in the dirt floor of the permanent council house. When they sat round the edge of the pit with their feet hanging down inside, they were little annoyed by the smoke, which escaped through a hole in the roof. Explain.
>
> What disadvantages of the Roman method of heating can you think of?

120. *Modern devices for heating the home: the fireplace. The fireplace in some form has been in use for centuries. Its increasing use entitles it to be classed among the modern devices for heating the home as well as among those of ancient times (Fig. 114, *B*). It has the advantages of being cheerful, of not taking up space in the room, and of insuring good ventilation because fresh air enters round the doors and windows, while the stale air goes out through the chimney. It also has a number of important disadvantages. Much fuel is wasted, since most of the heat from the combustion is carried by convection directly up the chimney. Moreover, it heats the room almost entirely by radiation and therefore unevenly. There are two reasons for this: (1) the radiant heat passes through the air



A B

FIG. 114. THE FIREPLACE IN THE OLD VAN CORTLANDT MANSION, NEW YORK CITY, AND DIAGRAM OF A MODERN FIREPLACE

In this room (*A*), famous in colonial history, Washington and other leaders were entertained; in (*B*) why do the convection currents move in the direction of the arrows?

without heating it to any great extent (see page 164), and (2) the convection currents in the room are moving toward the fire. Why do the convection currents move toward the fire?

Do convection and conduction have any part in heating a room with a fireplace?

Special Reports. Discuss the ventilating fireplace, fireplace cooking in colonial times (Fig. 240, p. 456), and the Franklin stove.

121. *The stove. Stoves have been in use less than two centuries. Until very recently the heating stove consisted of a closed iron box with a smoke pipe to remove the products of combustion. Within recent years very great improvements have been made in the heating stove.

*The modern heating stove is like an old-fashioned stove inside a steel jacket. It heats the room chiefly by convection, though it also heats by radiation. The heat from the burning fuel is conducted through the steel body of the stove. This heats the air between the stove body and the outside jacket, causing convection currents.

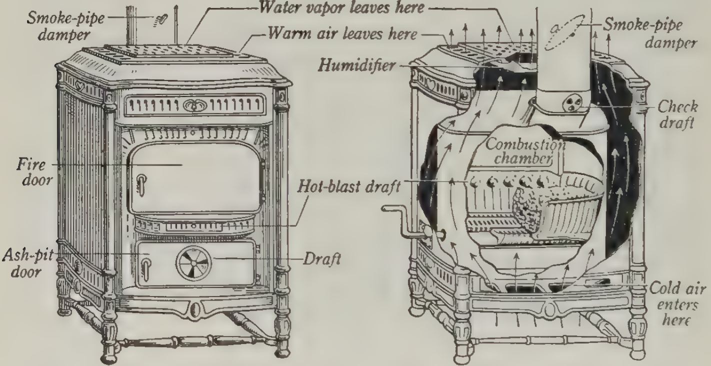


FIG. 115. A MODERN HEATING STOVE IS A HOT-AIR FURNACE

By referring to the text and the labels on these diagrams, explain how the stove operates

*The modern stove (Fig. 115) is equipped with three drafts and a chimney damper which together make it possible to control the rate of combustion. When the fire is first started, the damper and the lower draft are opened and the other two drafts are closed. This arrangement of damper and drafts allows the greatest possible amount of oxygen to pass up through the fuel. When the fire is burning vigorously the damper and the draft in the ash-pit door are closed to diminish the current of air through the fuel. The hot-blast draft is then opened. This allows oxygen to enter the fire pot just above the burning coal or wood. Here it increases the oxidation of the combustible[1] gases and also burns up many of the carbon particles which would otherwise make smoke and soot. By increasing the combustion the hot-blast draft increases the number of calories from the fuel without increasing the amount of fuel which is being burned. If it is desired to make the rate of combustion still slower, the check draft is opened. Cold air is forced into the smoke pipe through this damper, thereby reducing the amount of air which enters the smoke pipe from the fire pot.

Special Report. Describe and explain the action of the wood or coal cooking stove or range.

122. Furnaces. The pipeless hot-air furnace (Fig. 116) uses the same principle as the hot-air heating stove which has just been described. The air that enters the heating chamber of the furnace is air from the house; consequently it is already partly warmed.

*The ordinary hot-air furnace is equipped with pipes which carry the hot air to the various rooms (Fig. 117). Hot-air heating is frequently used in schools and other public buildings. Sometimes fans are used to assist in pushing the convection currents through the pipes.

Why is the outside of the hot-air pipes of bright metal covered with asbestos (see page 165)?

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[1] *Combustible* (kum bus′ti bl): able to burn. Thus wood and coal are combustible substances.

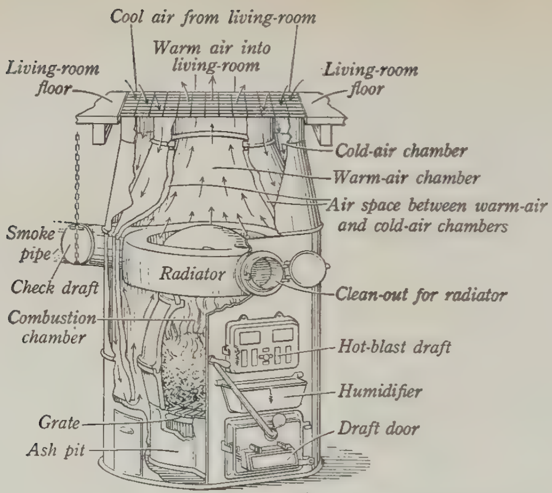

FIG. 116. DIAGRAM OF A PIPELESS FURNACE

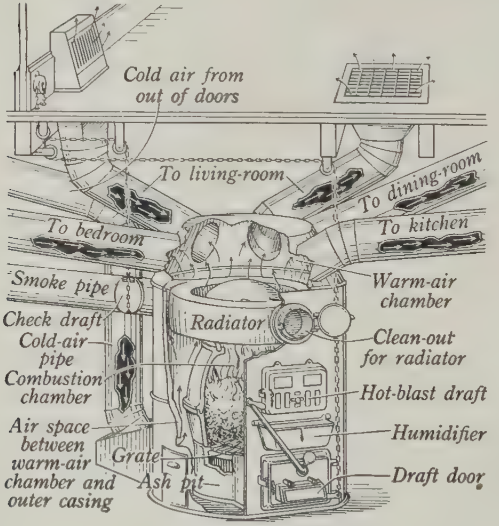

FIG. 117. DIAGRAM OF A HOT-AIR FURNACE

How are radiation, convection, and conduction used in the hot-air furnace? in the pipeless furnace?

123. *Hot-water heating. In the hot-water heating system, hot water carries the heat by convection as shown in Fig. 118. The furnace uses the principle of the water jacket. The heat from the burning fuel is conducted through the wall of the furnace to the water, which absorbs the heat. Convection currents are then set in motion in the water jacket and pipes. The hot water cools only a few degrees in the radiators, but the heat it gives off in cooling is conducted through the metal of the radiators.

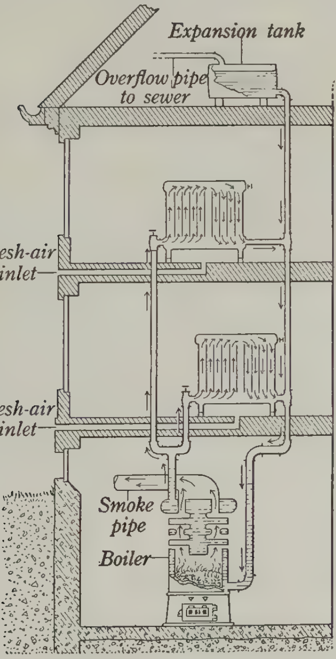

FIG. 118. DIAGRAM OF A HOT-WATER HEATING SYSTEM

Does the hot-water system heat the house mostly by radiation, convection, or conduction?

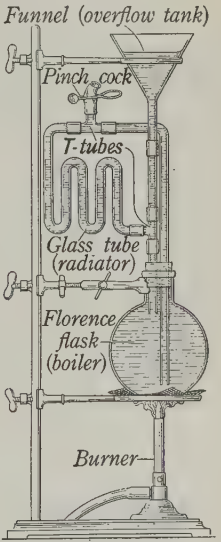

FIG. 119. A CLASSROOM MODEL OF A HOT-WATER HEATING SYSTEM

Part of this heat is radiated through the room, and the rest sets in motion convection currents which heat the room evenly.

> *Project.* To make a simple model of a hot-water heating system set up apparatus as in Fig. 119. Fill the apparatus from the overflow tank (funnel), but open the pinchcock above the radiator while filling the apparatus. Why? Do not allow the water to boil.

124. *Steam heating. In the steam heating system (Fig. 120) the boiler is partly filled with water. This is raised to the boiling point and evaporated by the heat from the burning fuel. The steam produces sufficient pressure in the tank to force some of the steam up through the riser pipe into the radiators. Some of the steam is cooled so much in the riser pipe that it condenses, but most of it condenses in the radiators. When the steam condenses, it gives up heat. This heat is conducted through the radiators and distributed through the rooms by radiation and convection. Steam heat is commonly used for large buildings and for groups of buildings heated by a central heating plant.

> *Special Report.* Describe the construction and action of the vacuum valve on steam radiators.

125. The three methods of heating compared. Of the three heating systems the hot-air system is the cheapest to install. It begins to supply heat to the rooms soonest after the fire is started. It gives least heat to the rooms for the amount of fuel burned, and it is liable to allow some of the products of combustion to leak into the hot-air chamber and thence into the rooms with the hot air. The hot-water system is slow to heat and is the most expensive to install, but once the water becomes hot it maintains a steady, even temperature. With the hot-air and steam systems, on the other hand, the temperature of the rooms is likely to vary greatly. The steam heating system is less expensive to install than the hot-water system, and probably gives more heat for the amount of fuel burned. The hot-air system circulates plenty of fresh air through the rooms, but the other two systems do not. With steam or hot-water heating, therefore, either the windows must be opened or special entrances for fresh air must be placed under the radiators. It is easier to maintain the proper amount of moisture in the air with a hot-air system.

Steam heating and hot-water heating systems are much cleaner than the hot-air heating system. Why?

Special Report. Describe oil heaters, their action and uses.

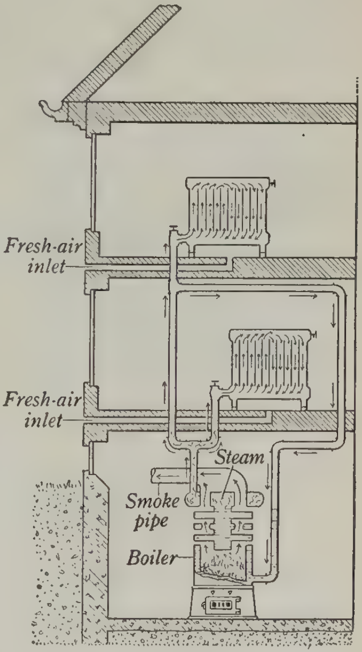

FIG. 120. DIAGRAM OF A STEAM HEATING SYSTEM

How does the steam heating system use radiation, convection, and conduction?

126. †Modern cooking ranges. Where gas can be obtained, the gas range is rapidly taking the place of coal and wood ranges. It is cleaner and more convenient and cooks the food more quickly. Where natural gas is obtainable, it is cheaper than wood or coal for cooking. Fig. 121 shows the principle of the burner of a gas range.

> *Special Reports.* Describe gas furnaces, gas fireplaces, kerosene ranges, and gasoline ranges, with their construction and methods of operation.

Where electricity is not too expensive the electric range is becoming more and more common. It is probably the cleanest and the most convenient of all the ranges, but it is also probably the most expensive to operate. Electric heaters also are convenient and clean, but they are very expensive to use.

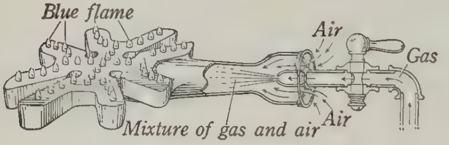

FIG. 121. EXPLAIN THE OPERATION OF THE GAS-RANGE BURNER

> In what respects is an electric heater like a fireplace? Compare the advantages and disadvantages of a fireplace and an electric heater.

127. The chief purpose of a chimney is to furnish a draft. Sometimes when the fire in the fireplace, stove, or furnace is first started, it burns slowly and smokes; that is, the smoke comes out into the house instead of going up the chimney. After the air in the chimney becomes warmed, the smoking ceases and the fire burns vigorously. Thus the chimney also carries off the products of combustion.

Smoke pipes and chimneys should be cleaned once a year. Such care will prevent the accumulation[1] of too much soot, which may ignite and cause chimney fires.

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[1] *Accumulate* (a ku'mu late): to collect or build by small amounts. *Accumulation* (a ku mu la'shun): the act of accumulating.

128. †Conserving heat in the house. Effective heating consists not only in producing heat in the house but also in conserving the heat in the house. We frequently hear it said that a house is "warmly built," or that it is a "warm" house. This statement usually means that the builder has made practical application of his knowledge of convection and conduction in constructing the house. He has not only used nonconducting materials wherever possible for the walls and roof but has also provided air spaces between the walls.

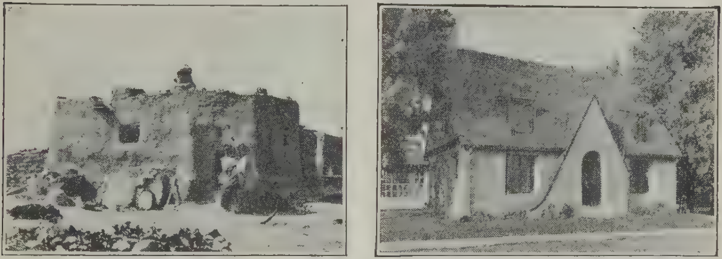

FIG. 122. PRIMITIVE AND MODERN DIRT-WALLED HOUSES

The one on the left was made by Indians in New Mexico; the one on the right is a modern city dwelling. What advantages are derived from having the walls so thick?

Why are brick, stone, sod, and dirt-walled houses (Fig. 122) cool in summer and warm in winter? Why are single-walled houses more difficult to maintain at an even temperature than double-walled houses? Why are air spaces left in tiles and concrete bricks intended for walls? Why is a house with an attic cooler in summer and warmer in winter than one without an attic? Why is a lath-and-plaster house a "warm" house?

Special Report. Diagram and explain the wall construction of a double-walled house.

129. *Solid, liquid, and gaseous fuels. Familiar solid fuels are coal, coke, wood, and charcoal. Familiar liquid fuels are petroleum, or crude oil, and the products of petroleum, chiefly gasoline; alcohol is another liquid fuel which is likely to increase in importance. Familiar gaseous fuels are natural gas, coal gas, and, to a small extent, acetylene.

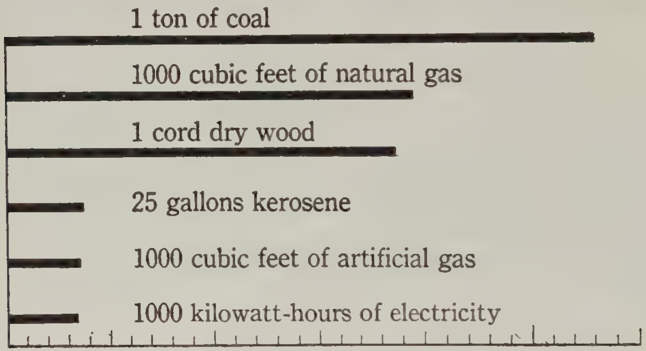

FIG. 123. GRAPH SHOWING THE RELATIVE HEATING VALUES OF COMMON FUELS

The scale at the bottom is for the sake of making comparisons easy. The graph shows that one ton of coal furnishes more heat than one cord of dry wood, or than the amount given of each of the other fuels. How many times as much heat is furnished by a ton of coal as is furnished by each of the amounts of other fuels given?

*The chief fuels used for cooking and heating in the United States and Canada are coal, gas, wood, electricity, and kerosene (Fig. 123). Although gasoline is used comparatively little in homes for heating and cooking, it must be classed with the important fuels because it is used in automobile and other gas engines. About twice as much heat for manufacture and industry is secured from coal as from gas, but about twice as much heat for homes is secured from gas as from coal.

Wood was probably the only fuel known to primitive man. It is still used as the chief fuel for homes in parts of the United States, Canada, and other parts of the world where it is sufficiently plentiful, though it finds relatively little use in industry. More than four fifths of the wood used in homes is burned on farms, and almost all the rest in cities of less than thirty thousand population. Coal, coal gas and natural gas, electricity, gasoline, and kerosene are rapidly taking the place of wood as a fuel.

> *Special Reports.* How are valuable raw materials wasted in lumbering, mining, and oil-refining? What data[1] can you find on fuel waste, fuel conservation, and the rate at which our fuels are now being consumed in the United States? Make a map showing where our chief fuels are now to be found. Make a list of modern inventions which increase the rate at which our fuel is being used up.

† Natural gas is cheap and is much superior to artificial coal gas. It is used in homes for cooking and heating and to some extent in such industries as making steel, pottery,[2] brick, and glass.

130. Coal gas, or cooking gas. In parts of the country where natural gas cannot be obtained cheaply, artificial gas is made from soft coal (Fig. 124). The coal is heated for several hours in special chambers called retorts. No air is allowed to enter the retorts. Gaseous compounds containing carbon and hydrogen are driven off by the heat. These compounds are allowed to bubble through water, and this cools them and condenses some into solids and liquids called coal tar. The gas passes through long vertical coils of pipe called the condenser. Here the rest of the coal tar condenses. Liquid containing ammonia collects on the surface of this coal tar. The gas then passes through a tall tower called the scrubber. This

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[1] *Data* (day′ta): facts and observations concerning any phenomenon or phenomena.

[2] *Pottery* (pot′er y): dishes and other vessels made of baked clay.

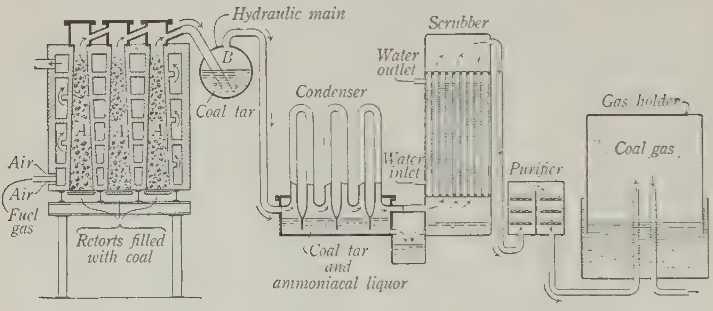

FIG. 124. DIAGRAM OF A COAL-GAS PLANT

With the aid of the text and the diagram, can you explain the manufacture of coal gas?

FIG. 125. A GAS STORAGE TANK AT OAKLAND, CALIFORNIA

What causes the top of the tank to rise and fall at different times? (Photograph by Ewing Galloway) scrubber is filled with loose pebbles or coke over which water is sprayed. In passing through the water the gas is made cooler, and any impurities in it are dissolved in the water and removed. The gas now passes into the purifier, which is a series of boxes fitted with frames covered loosely with lime or iron oxide, or both. These compounds remove the remaining impurities from the gas. The purified gas now enters the gas-storage tanks (Fig. 125), from which it is distributed to homes, factories, and business houses.

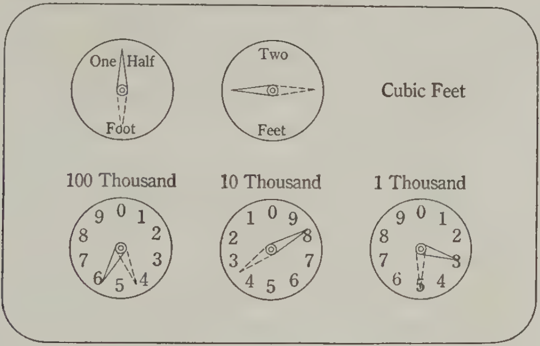

FIG. 126. THE DIALS OF A GAS METER

A ton of good gas coal produces about ten thousand cubic feet of gas, fourteen hundred pounds of coke, a hundred twenty pounds of tar, and twenty gallons of ammonia liquor. The coke is an excellent fuel. Valuable products made from the tar are used for preserving timber, for protecting paint, and in making tarred paper and black varnishes.

131. †The gas meter. Where natural gas is very plentiful, people are sometimes charged a certain fixed sum, or a "flat rate," and are allowed to use as much gas as they wish. Usually, however, the amount of gas burned is measured by a meter. The users of the gas are then charged a certain sum for each thousand cubic feet of the gas which they burn. Fig. 126 shows the dials of a gas meter. The dotted positions of the hands show where the hands were when the meter was last read. The reading was then 44,500 cubic feet. The present reading is 58,300; therefore 13,800 cubic feet of gas have been used between the two readings. At $1 per thousand cubic feet the bill would be $13.80. Make a diagram showing where the hands on the dials would be if the reading were 87,100 cubic feet.

132. †Dyes made from coal tar. When coal tar is distilled, it gives up substances from which medicines, explosives, perfumes, and dyes are made. More than five thousand dyes are known, most of which can be manufactured from substances distilled from coal tar. About nine hundred dyes are used.

Before the World War most of the dyes used throughout the world were made in Germany; relatively few dyes were manufactured in the United States. Our chemists had not then learned to make many of these dyes, because we had been obtaining them from Germany, where the secret of their manufacture was carefully guarded. During the war, when dyes could no longer be procured from Germany, our chemists began to experiment for the purpose of finding out how we might make our own dyes. They were so successful that they discovered not only how to make many of the dyes which formerly had to be brought from Germany but also how to make many new dyes.

*Woolens and silks are usually dyed readily by steeping them in water in which the dye is dissolved. Cotton, however, does not dye "fast" with many colors; that is, the colors wash out when the cotton has been dyed with them. Therefore cotton cloth is first soaked in a solution of certain compounds of aluminum, tin, chromium, or iron. The cloth will then dye fast if it is first exposed to steam before it is steeped in the dye. If a design is wanted instead of a solid color, the design is printed on the cloth in one of the metal compounds which we have just named. After this printing the cloth is exposed to steam and is then steeped in the dye. The dye remains fast in the metal compound and can be removed from the rest of the cloth, leaving the design.

133. † Charcoal. If wood is heated where the air cannot reach it, it does not burn or oxidize. The hydrogen, oxygen, and nitrogen of the wood combine with some of the carbon to form simple compounds. These compounds pass off, leaving charcoal, which is mostly carbon with some mineral matter. Charcoal is a good fuel, burning without flame and with little smoke and leaving the mineral matter in the form of a white ash.

Special Report. Charcoal has a number of uses other than as a fuel. How many can you discover and describe?

Project. To make some charcoal. Fill the bowl of a clay pipe with small pieces of wood tightly packed. Moisten some plaster of Paris to make a thick paste. Spread this paste over the top of the bowl so as to make an air-tight cover. When the plaster is thoroughly dry, heat the bowl of the pipe in a gas flame. See whether you can light the gases which escape from the end of the pipestem. When the gases are no longer given off, remove the pipe from the flame. Break off the plaster of Paris covering of the bowl. In what ways is the charcoal which you have made like the wood from which it was made? In what ways does it seem to be different? Make a small fire of the charcoal to see whether it is a good fuel.

Special Report. Describe the making of acetylene in the bicycle lamp and the uses of the acetylene torch.

134. †Alcohol. Alcohol is a compound of carbon, hydrogen, and oxygen. Wood alcohol is made from wood. Grain alcohol is made by the action of yeast[1] plants upon grains and potatoes. It burns without smoke and with a very hot, almost colorless, flame.

135. *Products of combustion. All fuels contain compounds of hydrogen and carbon. Therefore, whenever any fuel burns, the oxygen of the air combines with the compounds of hydrogen and carbon in the fuel. Thus carbon dioxide and water are always products of combustion. Sometimes when there is not enough oxygen present to burn up the carbon completely, carbon monoxide is formed instead of carbon dioxide. Carbon monoxide is a very poisonous gas. People die if the air they breathe contains one part of carbon monoxide for several hundred parts of oxygen and nitrogen. Carbon monoxide has no color and no odor, so that sometimes people are overcome by it without knowing it was present in the air. Carbon monoxide is formed in coal and coke furnaces and is given off in the exhaust from an automobile. People should therefore be sure that their furnaces do not allow any of the products of combustion to get into the house. They should be careful never to start the automobile engine when the doors of the garage are closed. They should be careful, too, never to inhale cooking gas, because it contains some carbon monoxide. Carbon monoxide is itself good fuel. It burns readily in air, forming carbon dioxide.

†Whenever ordinary fuel is burned, there is smoke. This smoke consists mostly of particles of carbon which have not been burned, with sometimes some very small particles of ash. The carbon is combustible; the ashes are incombustible. Hard coal and coke make little smoke;

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[1] *Yeast:* a very small plant (see Chapter XXII).

soft coal makes a great deal of smoke. If the combustion were perfect, all the carbon particles would be changed into carbon dioxide and water. When the carbon particles are not burned and are allowed to be lost as smoke, much good fuel is wasted. Moreover, the particles of carbon fill the air with soot. This soot not only does more or less harm to all who breathe it but also injures property. It is estimated that the damage done by soot to property alone in great manufacturing cities amounts to many millions of dollars a year.

†People are beginning to realize that the chimneys of homes and factories must not be allowed to pour smoke into the air. The best way to get rid of the smoke is to burn the carbon particles, or soot, before these leave the furnace. Special furnaces have now been designed which supply plenty of air and mix this air so thoroughly with the combustible gases that all the carbon is oxidized. Not only is the smoke thus practically all consumed, but much more heat is obtained from the fuel.

136. *Incombustible substances. Substances which do not oxidize readily will not burn readily; also, substances already completely combined with oxygen do not oxidize. Such substances are known as noncombustible substances or incombustible substances. Fire brick, asbestos, and clay are common incombustible substances.

How many incombustible substances can you list?

137. *Fire is both a friend and an enemy. Without the help and use of fire our modern civilization would not be possible. Yet when fire is not properly controlled, it becomes a terrible enemy. Many millions of dollars are lost every year through the destruction of homes and buildings by fires and through forest fires.

*Fire will continue to burn only when it has a constant supply of oxygen and when the fuel is kept at its kindling temperature (see page 186). Fires can therefore be extinguished (put out) either (1) by preventing oxygen from getting to the burning material or (2) by cooling the burning material below its kindling temperature, or (3) by doing both. Wrapping a rug or blanket round a person whose clothing is on fire is usually the easiest and quickest way to extinguish the flame. Thus the combustion stops because the supply of oxygen is cut off.

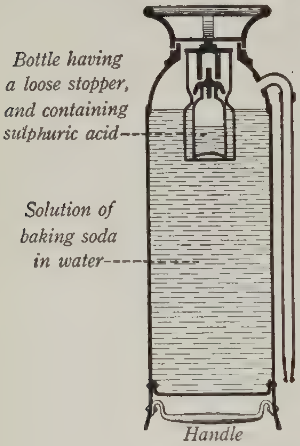
Bottle having a loose stopper, and containing sulphuric acid
Solution of baking soda in water
Handle

FIG. 127. A TYPE OF CHEMICAL FIRE EXTINGUISHER, KNOWN AS THE SODA-ACID EXTINGUISHER

138. Water valuable as a fire extinguisher. Water is chiefly used in fighting fires with fire engines and fire boats. It is mainly valuable as a fire extinguisher because it cools the fuel below its kindling temperature, but it is also valuable because it keeps oxygen away from the burning fuel. It does not serve to put out oil fires, however, because the oil floats on the top of the water, where it continues to burn and may spread if the water in flowing away carries it to other combustible materials. Much of the damage attributed to fire is really due to damage done by water.

139. *Chemical fire extinguishers. Chemical fire extinguishers find a valuable use in fire engines, public buildings, and homes. The commonest type of fire extinguisher (Fig. 127) puts out the fire with water and carbon dioxide (Experiment 5, p. 45). When the extinguisher is grasped by the handle, it is turned upside down. The little bottle of sulphuric acid is made so that its cork falls out when the extinguisher is turned upside down. The acid combines at once with the soda solution, forming carbon dioxide. The pressure of the carbon dioxide forces the carbon dioxide and water violently out of the hose. The water cools the fuel, and the water and the carbon dioxide together act like a blanket round the fire, keeping oxygen away.

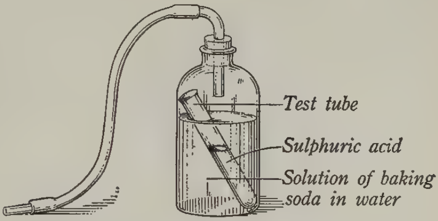

FIG. 128. CLASSROOM MODEL OF A FIRE EXTINGUISHER

Project. To make a fire extinguisher. Place a small test tube in a bottle (Fig. 128). Using a funnel, fill the test tube about a fourth full of sulphuric acid. Be careful not to spill any of the acid on your hands, your clothing, or the table. Close the bottle *tightly* with a one-hole rubber stopper equipped with a tube as in the figure. Using the funnel again, fill the bottle about two-thirds full of water in which you have first dissolved as much baking soda as possible. Build a small fire in the sink or out of doors. Hold the cork *tightly* with one hand while you turn the bottle upside down. With the other hand direct the end of the tube at the fire (Fig. 129). Do you get better results when you direct the carbon dioxide and water at the top of the fire or at the bottom of it? Explain. *Caution:* The carbon dioxide may be produced fast enough when the bottle is inverted to force out the cork even though you hold it tightly. Should any liquid strike your clothing, sponge the spots at once with dilute ammonia, then sponge again with water to remove extra ammonia.

In another type of fire extinguisher a small metal cylinder is filled with liquid carbon tetrachloride. The liquid is forced out of the cylinder with a piston. When the liquid strikes the fire, it immediately evaporates. The vapor is dense and incombustible and forms a blanket which shuts out the oxygen from the fire. This type of extinguisher is claimed to be most effective of all for fighting fires caused by defective[1] electric wiring.

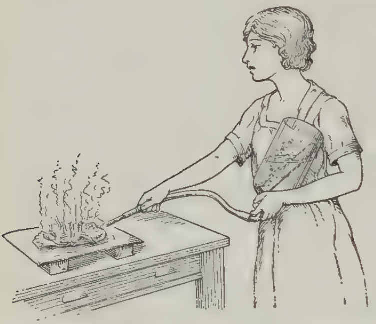
FIG. 129. HOLD THE CORK TIGHTLY WHEN YOU INVERT THE MODEL FIRE EXTINGUISHER

Still another type of fire extinguisher makes tough bubbles of carbon dioxide when the solution in it is played on a burning surface. This layer of thick foam forms a blanket which shuts out the oxygen. It is claimed that this extinguisher is the best yet devised for fighting oil and gasoline fires.

Special Reports. Describe a modern fire engine. Describe the sprinkler system of fire extinguisher. Figs. 130 and 131 show some ways of preventing fires. Explore your own home to see whether there are any places where a fire might be liable to start. Make a similar survey of your neighborhood. How many homes in your neighborhood are equipped with fire extinguishers?

140. †Providing for safety in case of fire. Schools and public buildings should be built with more than one safe way of getting out of each room in case of fire. Stairs should lead to the street, to an alley, or to an open court, and they should be inclosed with fireproof [1] materials. All

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[1] *Defective* (de fek′tiv): having defects; not normal, correct, or perfect.

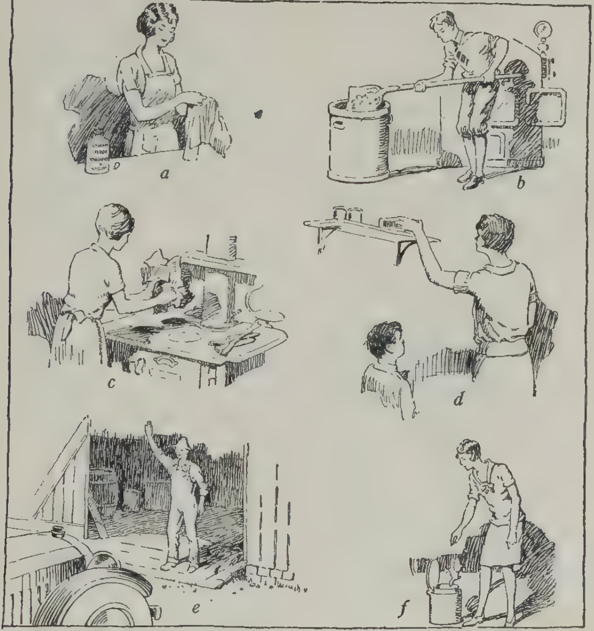

FIG. 130. PREVENTING FIRES WHILE WORKING

a: Clean clothes, especially silk, with carbon tetrachloride. Gasoline and naphtha are dangerous. The friction may produce a spark of electricity which will explode gasoline or naphtha. *b:* Put ashes into metal drums. Putting ashes into wooden barrels or boxes is dangerous. Why? *c:* Start fires with paper and kindling. Do not use kerosene or gasoline. Why? *d:* Keep matches on a high shelf where children cannot reach them. Do not let children play with matches or fire. *e:* It is not safe to use a barn for a garage. Why? *f:* Oiled cleaning cloths should be kept in metal cans. They sometimes take fire by oxidation from the air and so must not be left in closets doors should open outward. Fire extinguishers should be placed where they can be easily reached. Children should have frequent fire drills in schools in order to learn how to *walk* quietly to safety in case the building should take fire.

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[1] *Fireproof* (fyr′proof): made so that fire cannot get through; protecting against heat from fire.

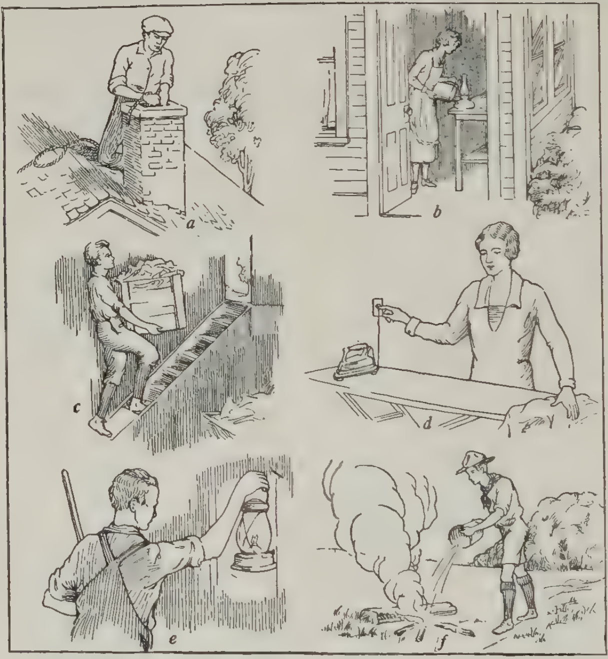

Fig. 131. Reducing Danger of Fire

a: Clean smoke pipes and chimneys once a year. Why? *b:* Fill gasoline and kerosene lamps by daylight in a well-ventilated room where there is no fire. Why? *c:* Remove waste paper and other combustible materials from your basement and attic. *d:* Turn off your electric devices before you leave them. *e:* Place lanterns and lamps where they cannot easily be knocked over. *f:* Be sure your fire is out before you leave it

141. *First aid for burns. In the case of a severe burn call a physician. An effective home remedy for slight burns is "carron oil." This is made by mixing equal parts of limewater and linseed oil and is applied on a cloth bandage.[1] Olive oil applied on a bandage is soothing and effective in the treatment of small burns.

Project. To practice with a fire extinguisher until you can put out a fire quickly and certainly. Build a good-sized fire in the yard. When it is burning vigorously, run from the fire to the place where the extinguisher is kept, secure the extinguisher, and extinguish the fire. Have somebody note how long it took you from the time you first started for the extinguisher until the fire was entirely out. Build the fire a second time and try again, to see whether you cannot cut down the time in extinguishing the fire. Write down in the form of brief notes the facts learned from this experiment which you think would help in case you needed to extinguish a real fire. The extinguisher will need to be charged again.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. Fuel must be warmed before it will burn.
2. Fire will not burn without **nitrogen** **carbon dioxide** **oxygen** **smoke** **argon.**
3. The temperature at which a fuel takes fire is called its ____.
4. A match is provided with a substance which takes fire at a low ____ and with another substance which furnishes ____ to help the burning.
5. A heating stove heats the room chiefly by conduction and radiation.

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[1] *Bandage* (ban′daj): a strip of soft cloth used in dressing wounds.

6. A fireplace heats the room chiefly by convection.
7. Smoke escapes from stoves and furnaces by conduction.
8. Two products which are always formed when fuels burn are ____ and ____.
9. Water puts out fires in two ways: (1) by lowering the ____ of the fuel and (2) by preventing the fire from getting fresh supplies of ____.
10. Bandage a burn with a mixture of equal parts of limewater and linseed oil.

SCIENTIFIC PUZZLES AND GAMES

Which of the five statements that follow this problem would a carefully trained scientist choose as the best? Select one or more of the scientific attitudes to justify your answer.

Problem. A man happens to wake in the night just as the clock is striking three. He immediately goes to sleep again. Though he is usually a sound sleeper, he wakes again the next night exactly at the same hour. He thinks little of the incident, but the third night he wakes again as the clock is striking three and hears somebody trying to break into the house. The man concludes that in some way his waking on the *two* preceding nights at *exactly* the same hour that the robber tried to enter was a warning, or at least had some connection with the robber's attempt.

1. The man's conclusion is sound, without doubt.
2. It is extremely unlikely that the conclusion is sound.
3. It is unlikely that the conclusion is sound.
4. The conclusion is probably sound.
5. It is possible that the conclusion is sound.

UNIT VI. HOW WEATHER AND CLIMATE AFFECT US

CHAPTER XIV

USEFUL KNOWLEDGE ABOUT THE WEATHER

Some Questions this Chapter Answers

What is the relation between air temperatures and pressures and winds? What determines the speed and direction of winds? What causes land and sea breezes? What are cyclones and anticyclones? What causes tornadoes? What is the water cycle? When is air dry? When is it humid? What is the relation of humidity to health? How are various kinds of precipitation, such as dew, clouds, rain, and hail, produced? What are thunderstorms and cloudbursts? What causes winter storms and blizzards?

142. Air movements and air pressures. The air is hardly heated at all by the sun's rays as they pass toward the earth, but is heated considerably by reflection of heat from bodies of water and from the earth. It is also heated by conduction through direct contact[1] between the air and objects on the earth's surface. Movements of air are constantly occurring because of differences in the temperature of the air at different places.

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[1] *Contact* (kon′takt): the touching of two objects.

*Air acts as the water does in Experiment 27, p. 166. Air is heated from several sources, and flows much more readily than water. We therefore have air pressures and currents in many directions. The pressure of cold air may become very great, and the hot and less dense air may be driven under very great pressure. These air movements are commonly called *winds*. The rate and direction of winds depend chiefly upon the air pressures which result from the unequal heating of the air.

*We learned that the barometer is used to measure the pressure of the air (see page 18). At sea level under normal conditions the barometer would probably register about thirty inches or slightly less. *A region of higher barometric*[1] *reading is spoken of as a high-pressure area or briefly as a "high"; one of low barometric reading, as a low-pressure area or a "low."*

143. *The winds. It is commonly known that the polar[2] regions are cold. The earth receives more heat in the regions near the equator[3] than in the polar regions. If no other causes were involved, the air from the regions near the equator would always be forced upward by the colder polar air. In that case the winds near the earth's surface would always blow toward the equator and would be relatively cool, and the winds high above its surface would blow toward the poles and would be relatively warm. This tendency is in operation all the time, but is affected by many other causes. It is clear that if there were different amounts of heating at the same altitudes or about the same, there would always be air movements, or winds, and such *are* almost always to be noted. They differ in rate and strength because of differences in temperature and pressure and in the masses of air which are moving.

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[1] *Barometric* (bear o met′rik): having to do with a barometer.

[2] *Polar* (po′lar): having to do with the north and south poles.

[3] *Equator* (e kway′tor): a line which is imagined to be round the earth halfway between the north and south poles of the earth. *Equatorial* (e kway-to′ri al): having to do with the equator.

The earth's rotation[1] affects the direction of prevailing winds. In the region north of the equator the prevailing winds do not blow in a north-and-south direction, but in general from northeast to southwest (Fig. 132); in the region south of the equator the winds do not blow in a north-and-south direction, but in general from southeast to northwest (Fig. 132). These prevailing winds are called *trade winds*, because their force and direction near the earth are so nearly constant that they have been much used by ships in carrying on trade between countries. The rate and movement of trade winds varies from ten to thirty miles per hour.

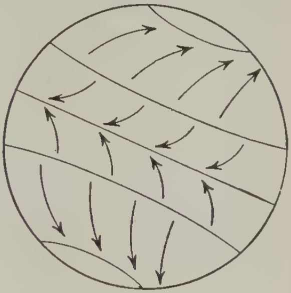

FIG. 132. DIAGRAM SHOWING AIR MOVEMENTS

The earth rotates from west to east. This rotation causes the winds to curve from the true north and south direction as indicated by the arrows. Why are sailing ships frequently unable to make progress when they are near the equator?

Near the equator, wherever local factors do not interfere,[2] there is a wide area of ascending heated air. Rising and falling currents of air do not move sailing ships; hence this wide area of ascending air is called the region of *equatorial calms*, known as the *doldrums*.

144. †Land and sea breezes. Land and sea breezes are matters of common knowledge. On a hot day the soil, the rocks, and the buildings of the land become heated more rapidly than does the water of lakes and oceans. The air above the land is expanded, and air from above the water flows in and crowds it upward. This is the cause of the *sea breeze* of the daytime. Water loses its heat much less rapidly than land does, and at night the *land breezes* are produced. Naturally the sea breezes are most extensive in summer weather and in hotter regions. They may affect the land surfaces to a distance of twenty-five miles or more from the bodies of water, but they are most noticeable within the first two or three miles. It is partly because of these facts and principles of the action of air currents on the borders of bodies of land and water that such regions are sought as summer homes and places of recreation[1] in many countries; for example, the regions near the Great Lakes and along the ocean shores.

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[1] *Rotate* (ro′tate): to spin like a top. *Rotation* (ro ta′shun): the act of rotating.

[2] *Interfere* (in ter fear′): to get in the way of or to oppose.

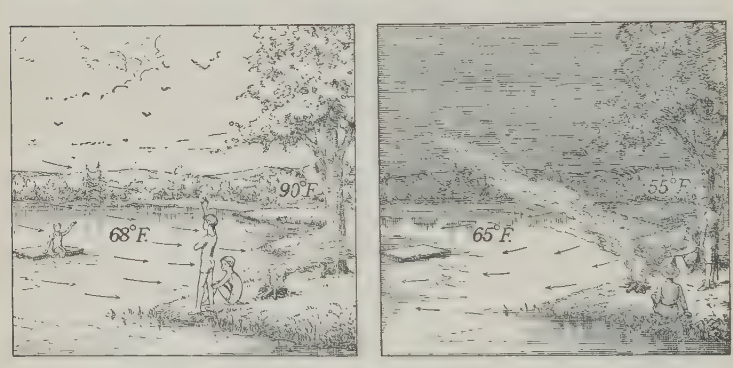
90°F.
68°F.
55°F.
65°F.

FIG. 133. LAKE AND LAND BREEZES

Near the shores of large bodies of water unequal temperatures produce the winds

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[1] *Recreation* (rek re a′shun): pleasant pastimes which refresh mind and body.

Fig. 133 illustrates the cause of lake, river, and sea breezes. In the material which follows, can you fill each blank with either the word "land" or the word "water" so as to give a correct explanation of these breezes?

When the sun is shining upon the land and water the ____ heats more rapidly than the ____. The air above the ____ therefore heats more rapidly than the air above the ____. The air above the land therefore expands more rapidly than the air above the water. A partial vacuum, or reduced air pressure, is thus produced above the land. The greater air pressure over the ____ forces the colder air toward the ____. During the day, then, a breeze is blowing from the water to the land, and the convection currents over the land are being forced upward. At night, however, the land radiates its heat away faster than the water. Consequently the ____ becomes cooler than the ____. The air over the ____ cools faster than the air over the ____. The air over the land therefore contracts faster than the air over the water. The air pressure over the land consequently becomes greater than that over the water. At night, then, the greater air pressure over the ____ forces the air currents toward the ____, causing the land breeze.

*On both land and water, wind storms of various kinds may occur whenever differences in air pressures have developed. These may be quite local, brief, and of little effect, like the small "whirlwinds" one may observe on almost any summer day.

145. *Cyclones and anticyclones. A cyclone, or low (Fig. 134), is a large moving area of air which has low pressure. Cyclones travel in general from west to east. From one to three cyclones may be expected to pass across North America each week. The center of a cyclone, however, may travel in a day over a distance of from a few hundred

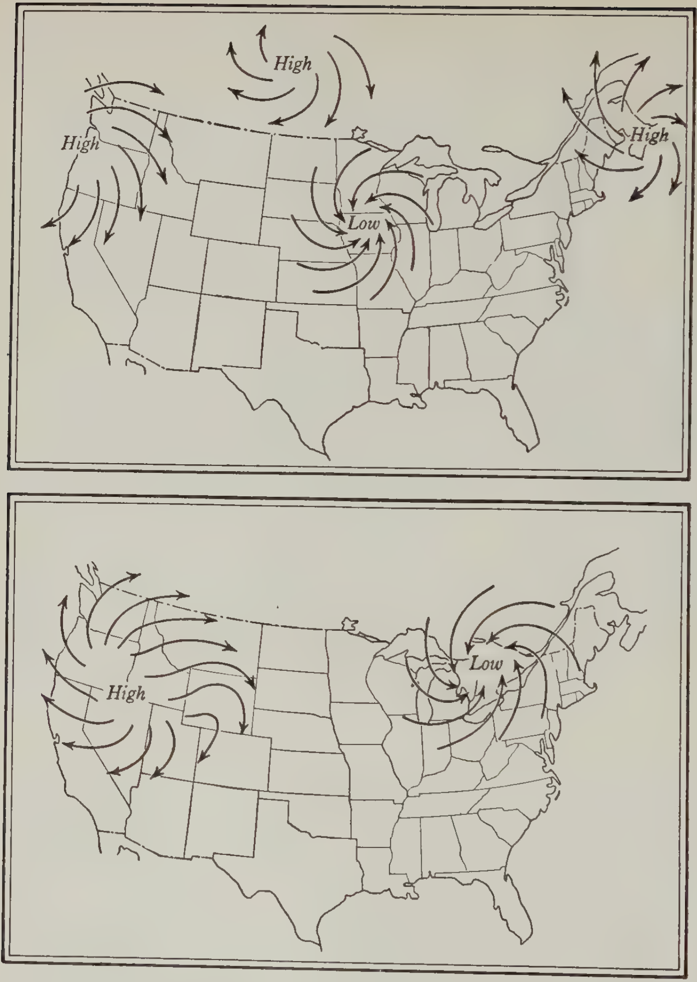

FIG. 134. HIGHS AND LOWS ON TWO SUCCESSIVE DAYS

Highs and lows are great eddies, or whirlpools, of air which rotate in the directions shown in these figures. Air currents are rising in the center of a low and falling in the center of a high. In which direction have the highs and lows traveled?

miles to more than a thousand. The winds of a cyclone are not often violent, though they may move as rapidly as from sixty to eighty miles per hour. At these times their pressure of ten pounds or more per square foot may blow away insecure objects. Such a pressure is enough to make a person aware of the push of the wind when he walks against it. It is only very unusual winds which reach a speed of one hundred miles per hour, and at that speed the enormous force against trees or walls of houses sometimes pushes them over. Weather conditions within a low are often such as to cause storms which may be accompanied by rain, snow, sleet,[1] or hail. As the cyclone moves forward, higher and colder air flows downward and outward, following the path of the cyclone. This air movement is called an anticyclone. The anticyclone is a high-pressure area (Fig. 134). Cyclones and anticyclones are large whirling bodies of air which move across the country while rotating in opposite directions.

146. *The tornado. The tornado (Fig. 135) is the type of violent and destructive[2] storm sometimes incorrectly spoken of as a cyclone. A tornado occurs after a period of warm, calm weather. One explanation of the cause of tornadoes is this: The air next to the earth becomes heated, but convection currents are delayed. The result is that there is next to the earth's surface a stratum of warm air, above which, like an invisible roof, is a stratum of cold air. Finally, the pressure of the expanding warm air becomes great enough to break through a thin portion of the colder stratum above. Immediately the warm air is pushed from every direction toward this hole, in much the same way that the water is pulled in every direction toward the drain when the stopper is removed in a washbowl. The result is a whirling wind of great violence covering a relatively small area. This tornado moves across the country in general from southwest to northeast (Fig. 136) with the low, in somewhat the same way that an eddy[1] in a river travels downstream with the current.

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[1] *Sleet:* rain with snow or ice in it, or rain which freezes while falling.

[2] *Destructive* (de struk′tiv): liable to destroy.

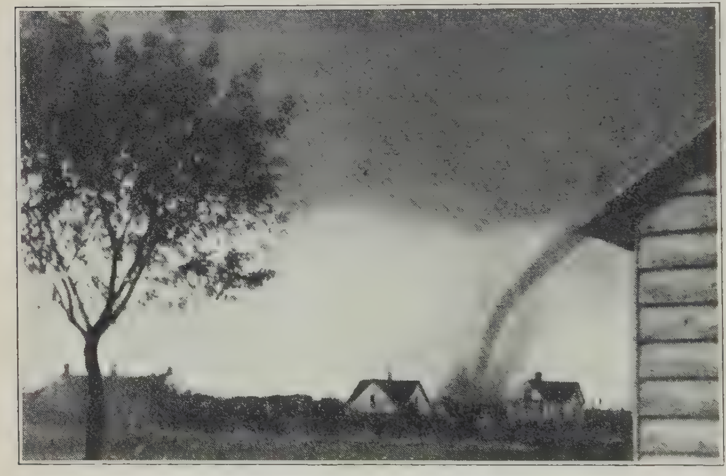

FIG. 135. A TORNADO

Note the dust cloud at the base. What do you think makes the tornado visible? (Photograph by United States Weather Bureau)

Fig. 136 is a map showing a section of the path of the tornado of March 18, 1925. This tornado swept across southern Illinois and Indiana in mid-afternoon, killing and injuring about four thousand people and causing millions of dollars of property damage. The storm started in northwestern Arkansas, then swept northeasterly through the towns shown on the map and died out in central Indiana. The main path of the tornado was about one hundred and sixty-five miles long and about three hundred feet wide. The force of the wind was so great that whole houses were moved from their foundations, sides of buildings were ripped off, timbers from wrecked buildings were carried as far as fifteen miles, and smaller objects farther.

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[1] *Eddy* (ed′dy): a small funnel-shaped whirl in water.

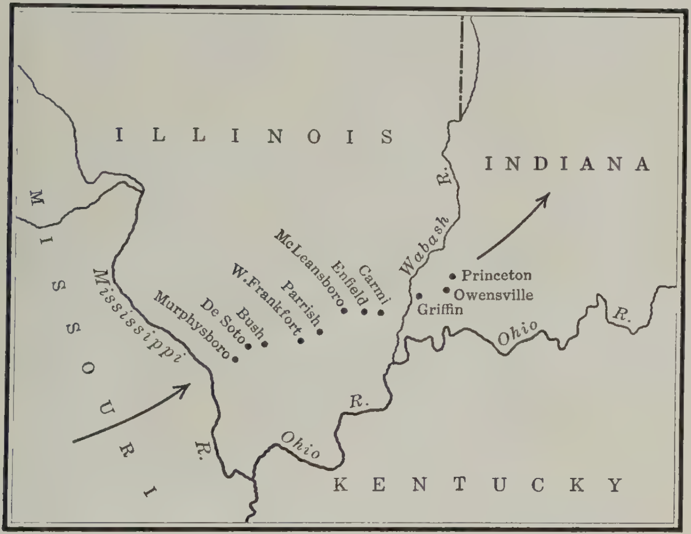

FIG. 136. THE PATH OF A TORNADO

If you were facing a tornado coming directly toward you, what would it be safest to do: stand still? run toward the tornado? directly away from it? toward your right? toward your left?

147. Water in the air. *Experiment 32.* How can you condense water from vapor? Hold a cold substance, such as a piece of bright metal, above a beaker of boiling water. Observe the surface of the metal to see whether water collects on it. Blow your breath upon a cold piece of glass or a windowpane and see whether water is condensed from your breath. Make a statement of your conclusion.

*When heated air which carries water vapor becomes cooled, the vapor condenses and forms visible drops. In fact, this condensed vapor produces an extremely small cloud, from which a small rain may be produced. If a cold substance is held in the steam for a moment, drops of water will be condensed from the air and will appear on the surface of the cold object. Similarly, if a jet of cold air be sent into the vapor-laden air, small drops of water will form and drop like rain.

148. *The water cycle. We have learned that water evaporates into the air more or less rapidly from all bodies of water, from moist soil, from the leaves of trees, from anything, indeed, which contains moisture (see page 48). It may condense from the air whenever the air is cooled enough; that is, unable to carry its load of water vapor. Whenever the air has all the water vapor it can hold, it is said to be *saturated* or to have reached the *saturation point.* Saturated air is like a sponge which has taken up all the water it can possibly hold. When air is cooled enough, it must give up part of its load of water vapor, just as the sponge when squeezed must give up part of its load of water. When air is cooled and reaches the temperature at which part of its water begins to be condensed as very fine drops, it is said to have reached the *dew point,* and the fine drops are called *dew.* Dew is really an extremely fine form of rain, except that the drops are condensed from the air upon solid objects and do not fall through the air as drops of rain. The water of the earth is being continually evaporated and condensed. Thus, for many millions of years the same water has been going through the water *cycle*[1] of evaporation and condensation.

---

[1] *Cycle* (sy'kl): a round, or series, of events or conditions which is continuously repeated.

149. *Dry air and humid air. When there is little water vapor in air, it is properly called dry air; when it carries much water vapor, it is properly called moist, or *humid*, air. Dry air will take up water vapor more rapidly than air which is partly saturated, just as a dry sponge will take up water more rapidly than one which is already partly filled, or saturated, with water. Therefore in places or at times when air is being heated, it feels dry and has increased its capacity to absorb water. The limit of wetness, moistness, or humidity of air at a given temperature is reached when the air at that temperature will take up no more water. If air at a given temperature holds only half the water vapor it might carry, it is relatively only half as humid as it might be; that is, its *relative humidity* is half, or 50 per cent, of what its humidity might be.

150. †Humidity and health. The air indoors is constantly receiving moisture from several sources: (1) plants in the room, (2) people's breath, (3) the evaporation of perspiration[1] from people's bodies. Therefore in badly crowded rooms in which the air is not circulating, the air may become too humid; that is, it may contain too much moisture for health. Our clothing prevents free circulation of air round our bodies. Hence as perspiration evaporates from the skin, a hot blanket of moist air is formed next to our bodies. This layer of humid air interferes with further evaporation of perspiration, and does not allow the skin to become cooled. If the air is kept in circulation, however, this humid air is removed and evaporation of perspiration from the skin takes place, using up much heat from the skin and thus making us comfortable (see page 153).

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[1] *Perspiration* (pur spi ra'shun): moisture given off by the body through the pores of the skin.

†In winter, however, there is usually too little moisture in the air inside the house. When the cold air from out of doors is warmed, its relative humidity may become as low as 20 per cent. The low relative humidity causes too rapid evaporation of perspiration from the skin, with the result that we become chilled, especially if there is a strong draft. Under these conditions we are apt to think that the room is cold, though the thermometer may register 70° F.

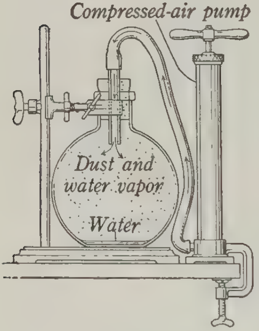

FIG. 137. PRODUCING FOG IN A BOTTLE

†Furnaces and stoves are sometimes equipped with pans called humidifiers (Figs. 115 and 116, pp. 190, 192), to give the air more moisture. Humidifiers to give best results should be filled only with soft water.

For public buildings, such as theaters and schools, the air is often humidified successfully by spraying water or sending jets of steam into the air while it is being heated and before it is forced into the rooms.

151. *Winds, fogs, clouds, and rainfall. When air that is carrying almost or quite a full load of water vapor comes in contact with cooler air, part of the water vapor is condensed and may appear in any one of several forms of precipitation.[1] If the condensation occurs slowly, as during a summer night, the moisture may appear as *dew*; if the condensation is general in the air near the earth, a *fog* results. The fog is in reality a low *cloud* of moisture condensed on dust particles in the air.

---

[1] *Precipitation* (pre sip i ta′shun): condensed water vapor, as in dew, fog, mist, rain, snow, sleet, and hail.

Experiment 33. Can fog be produced in a flask? Pour a small amount of water into a flask. Put some chalk dust into the flask. Close the bottle tightly with a one-hole rubber stopper (Fig. 137). Pump enough air into the bottle to blow out the cork. What do you observe in the flask? Can you explain what has occurred? Remember that when a gas such as air is compressed, it becomes warmer, and that when it is allowed to expand, it becomes cooler (see sections 97–98, pp. 152–153).

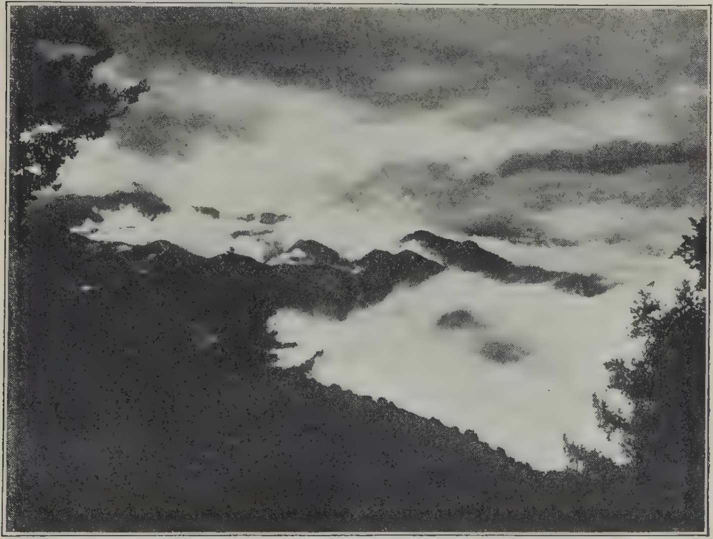

FIG. 138. NIMBUS OR RAIN CLOUDS (DARK) ABOVE, WITH FOG BELOW

Photograph by United States Weather Bureau

> Why are fogs common around large cities and around floating masses of ice in the ocean?

*When the condensation occurs at higher altitudes any one of several kinds of clouds may appear. The kinds of clouds depend on the temperature and on the movements of the air in which they are. The heavy, dark *nimbus* clouds (Fig. 138), from which rain or snow may fall, are not usually regular in form. These nimbus clouds are rarely over half a mile high. They are commonly much lower. Layers, or strata, of low drifting clouds called *stratus* clouds (Fig. 139) are not usually rain-producing. They commonly occur from a few hundred feet above the earth to about a thousand feet above it. The thick, rolling, mountain-like masses are the *cumulus* clouds (Fig. 140). In height they begin at about two thousand feet and may extend above the earth more than four miles. Their lower

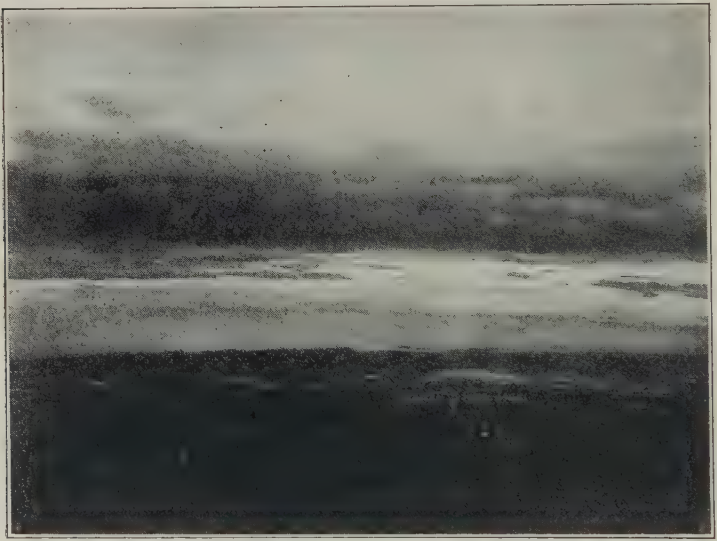

FIG. 139. STRATUS CLOUDS

These clouds are at two levels, one high and the other almost on the ground. (Photograph by United States Weather Bureau) surfaces appear almost level; their upper surfaces are like dome-topped mountains. The very high, white, flying *cirrus* clouds (Fig. 141) are thought to be flying masses of snow or sleet being carried along by the cold upper layers of air. They are usually five miles or more above the earth. There are other types of clouds, but the ones named are the leading and most easily recognized types.

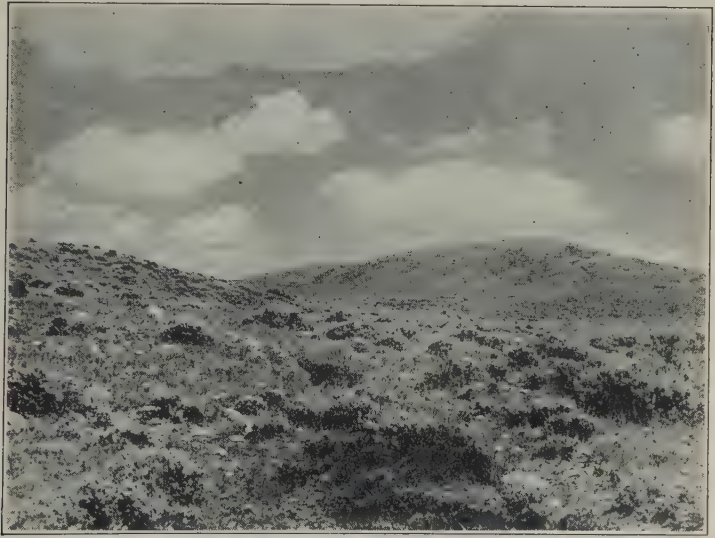

FIG. 140. CUMULUS CLOUDS

Photograph by Gayle Pickwell, taken in Wyoming

*We do not usually think of it as raining unless water is falling upon the earth. A very high cloud may produce rain, snow, or even sleet, and this may fall until it comes into a lower stratum of dry and warm air, which may evaporate the precipitation without its having reached the earth. Particularly might this occur if the raindrops were as small as one fiftieth of an inch in diameter,[1] as sometimes is true. The largest raindrops, which may occasionally reach even one fifth of an inch in diameter, are less likely to be wholly evaporated before passing entirely through a layer of warm, dry air closer to the ground.

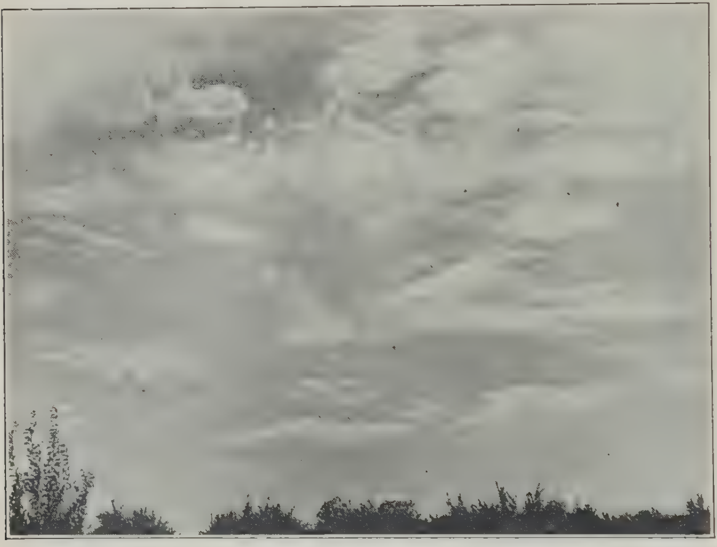

FIG. 141. CIRRUS CLOUDS ABOVE AND A FEW SMALL SCATTERED CUMULUS CLOUDS BELOW

Photograph by Gayle Pickwell, taken in California

* Hail usually forms in high clouds. The water condenses as rain and freezes, or condenses as snow which melts and then freezes again. These frozen drops may grow larger as water continues to condense and freeze in layers on the outside of the drops as they fall. Hailstones two or three inches in diameter have been found. Hail storms are sometimes the cause of heavy damage to crops and to farm stock.

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[1] *Diameter* (di am′e ter): the longest distance across a circle.

152. *Thunderstorms and cloudbursts. Rainfall is often accompanied by lightning and thunder. The lightning (see Chapter XXIX) is the flash resulting from an electric discharge between the electricity in the clouds or between the clouds and the earth. The sound of thunder is probably caused in much the same way as the noise of the explosion in a gas engine: by the sudden expansion of the

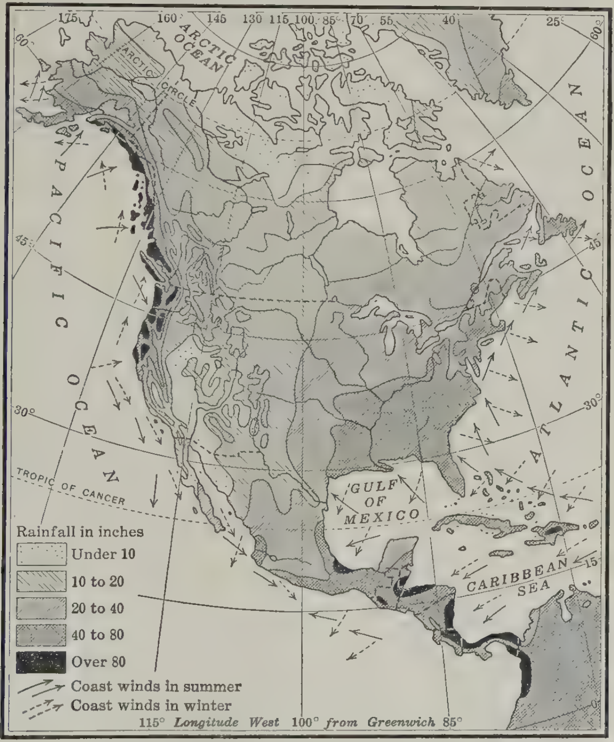

FIG. 142. MAP SHOWING PRECIPITATION

In what regions is precipitation heaviest? lightest?

air as it is heated along the path of the lightning. Thunder is harmless. Many superstitions have developed regarding lightning and thunder. As is so often true in studying nature, a little real knowledge serves to remove most of our fears.

When precipitation occurs very rapidly it is sometimes called a cloudburst. A cloudburst may occur when the air is fully saturated and close to the earth, and is cooled very suddenly. Cloudbursts are usually local. Cases are known in which during a cloudburst five or six inches of water have fallen within a few minutes.

Precipitation on the earth's surface is measured in inches (Fig. 142). Snow and hail as well as rain are caught in special instruments which measure and record the precipitation. The number of inches recorded is the same as the depth of a pond would be increased if all the precipitation from directly above the pond were to fall into it and none were lost. Nine inches of snowfall is equal to about one inch of ordinary rainfall.

153. Winter storms and blizzards. We associate tornadoes with warm or hot weather in somewhat the same way that we associate blizzards with cold weather. The kind of heating of the air which causes tornadoes does not occur in the coldest weather. In winter widespread areas of very cold air may move rapidly into equally extended areas of warm and moist air. At such times the sudden cooling may cause a heavy fall of snow. Sleet may also be formed and rain may freeze as it strikes, forming heavy coatings on trees, houses, fences, and even on animals that are exposed to it. Hard-frozen snow and sleet may be driven by the winds with great force, sometimes making it impossible for one to walk facing the wind. Men and animals sometimes become lost in such blizzards, and may even be covered by the blinding and drifting snow. Blizzards are most severe in the prairie countries, since in these open spaces the winds have a clear sweep over the land. In such level regions there are few objects by which a man out in a blizzard may guide his course.

The incoming colder air of the blizzard is usually from the north or northwest, hence the name "norther," sometimes applied to these storms. The name "blizzard" is applied only in regions where snow falls; in the Southern states norther is more commonly used.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. Winds blow from places where the pressure is less to places where it is greater.
2. A "high" is a region in which the barometer reads more than ____ inches.
3. Winds blow from places where the temperature is high to places where it is lower.
4. Another name for cyclone is **hurricane** **tornado** **low** **high** **wind storm**.
5. When water vapor is cooled, it condenses upon cold objects close by.
6. The evaporation and condensation of water following each other in endless succession is called the water ____.
7. Rain clouds are usually **stratus** **nimbus** **fractus** **cumulus** **cirrus**.
8. Frozen rain falls as **dew** **snow** **hail** **blizzards** **frost**.
9. Rain, hail, sleet, snow, dew, and frost are all forms of precipitation.

CHAPTER XV

RELATIONS OF WEATHER AND CLIMATE TO LIVING THINGS

Some Questions this Chapter Answers

What are the differences between weather and climate? Are most of the sayings about the weather accurate predictions? In what ways does the United States Weather Bureau serve the country? How does one read a weather map? How are plants and animals able to endure changes of climate? How is vegetation suited to the amount of rainfall? How do bodies of water affect the climate? How is climate related to progress?

154. †Differences between weather and climate. In common conversation the terms "weather" and "climate" are used as if they meant the same. They do not. The conditions from day to day with respect to temperature, air pressure, humidity, rainfall, clouds, sunshine, and the winds make up the *weather*. The *climate* of any region is the average of these weather conditions over a long period of time. The weather changes constantly from hour to hour, from day to day, and from month to month. Although many people believe that the climate changes frequently, there is no change that can be noted in climate from year to year. Such changes as are large enough to be noted occur only after centuries or even thousands of years.

155. Weather predictions.[1] The weather is a common topic of conversation possibly because weather plays so large a part in determining what we can do and how we can do it. There are few topics about which there are so many sayings, guesses, and superstitions. The superstitions, the guesses, and many of the sayings are without foundation. Some of the sayings have more or less real observation to support them. When one says "The rain crow (the yellow-billed or black-billed cuckoo, Fig. 218, p. 396) is singing, and that means that there'll be a rain before night," he is merely repeating an old superstition for which there is no known foundation. The saying "It rained on Saint Swithin's Day and will therefore rain on each of the forty following days" can be proved to be superstition merely by keeping careful records for a year or two. Even if in one year it should rain in a certain place on forty successive days, records for added years would be needed before a rule could be stated. It is a different kind of sign when the water pitcher "sweats"; that is, when water condenses as dew and runs down on the outside of a pitcher of cold water. Even this phenomenon does not *prove* that it will rain; but it does show that there is enough moisture in the air so that the reduction in temperature close to the outside of the pitcher causes water to condense from the air upon the pitcher. It also shows that rain would be likely to fall if a general and cooler air current should flow into the region and lower the temperature of the air.

*Predictions concerning weather can be safely made only through a study of air pressures, temperatures, prevailing winds, and other factors, and through conclusions which one's study may give about the results which these factors seem likely to produce.

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[1] *Prediction* (pre dik′shun): a prophecy about events that have not yet occurred. *Predict* (pre dikt′): to prophesy.

156. *Importance of the United States weather service. The Weather Bureau is a division of the United States Department of Agriculture. It has made extended and detailed studies of the weather of the entire country. It has studied the surrounding countries and bodies of water. Weather has no regard for boundary lines. The Weather Bureau has established stations in larger cities throughout the entire country. From these stations the reports are

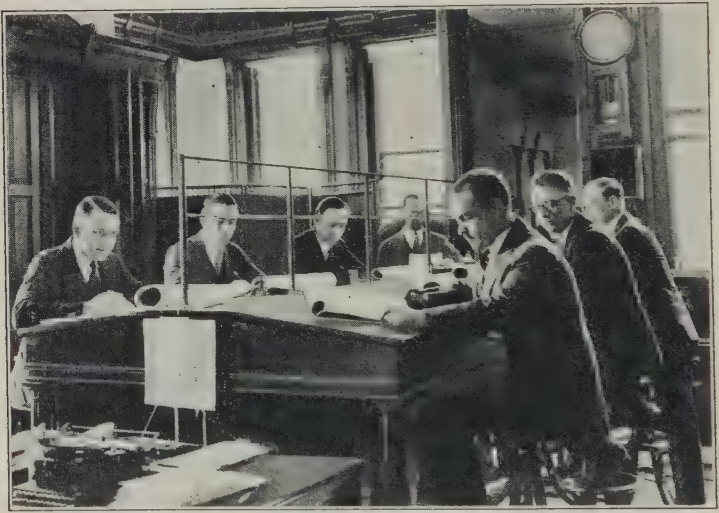

FIG. 143. FORECAST MAP ROOM OF WEATHER BUREAU AT WASHINGTON, D.C.

The men are recording data received from over two hundred regular observing stations in the United States, Alaska, and the West Indies, with added data from other countries. These data are studied by experts trained to predict the weather conditions which may be expected to prevail during the following thirty-six to forty-eight hours. (Courtesy of the United States Weather Bureau)

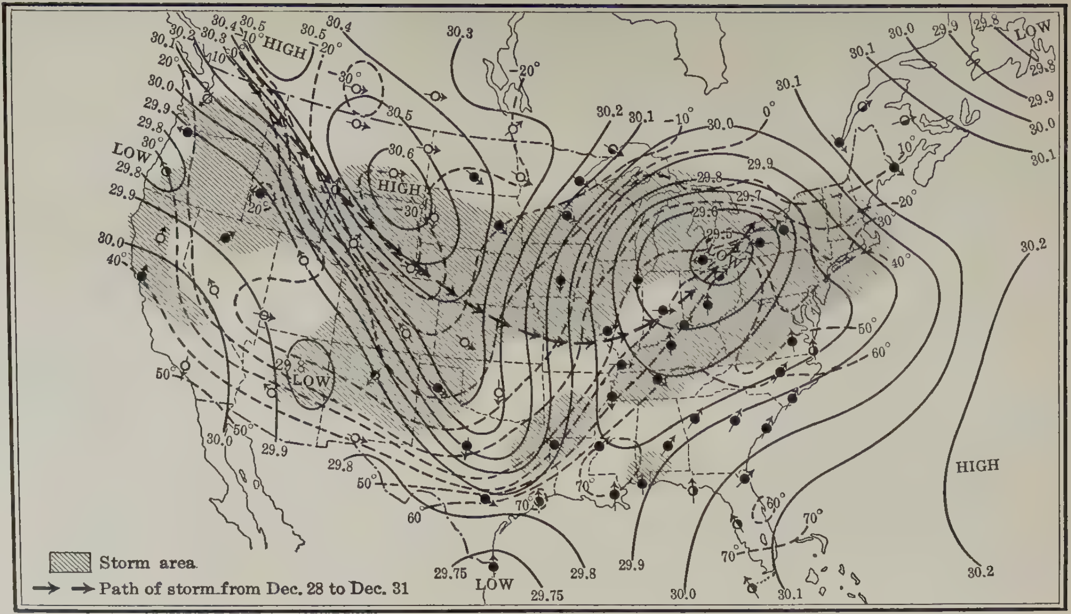

FIG. 144. WEATHER MAP, DECEMBER 31, 1923. THE PATH OF A SEVERE STORM

Note the positions and shapes of the highs and lows. The heavy arrows show the path of the storm center since December 28. Was there precipitation (rain or snow) upon the United States on this day?

telegraphed to the Washington Office, where the data are charted and the conditions and tendencies recorded (Fig. 143). Very complete and detailed weather reports are then sent out by telegraph and radio (see Chapter XXXII) all over the country. Weather maps (Fig. 144) are distributed by mail so that all citizens may know the weather that is likely to be had for the day or more to follow. Predictions are fairly accurate for two or three days during normal periods. They cannot be expected always to be accurate, since many unexpected factors may be introduced.

*This service from the Weather Bureau is of the greatest value and importance (Fig. 145). The farmer may learn whether the weather will be favorable to his plowing, planting, or harvesting. The shipper may know whether to prepare his perishable goods for cold weather or for hot weather. The transportation company may know whether to expect rains, snows, or unfavorable temperatures along their routes. In river valleys flood conditions may usually be known long in advance of their arrival. Airplane journeys are planned after consulting the weather predictions.

> *Special Report.* Secure a weather map from your nearest Weather Bureau station and find how many kinds of information it provides.

157. †Reading a weather map. If you will refer to the weather map of the storm (Fig. 144) you will find that it gives much interesting and valuable information. The barometric pressures are marked on the curving black lines surrounding the centers of the highs and lows. The dotted lines up and down and across the country indicate places having the same temperatures, the little circles indicate how cloudy the weather was at various cities, and

FORECAST UNTIL 8 P.M. SATURDAY

For Detroit and Vicinity: Friday night unsettled with showers or thunderstorms and slightly warmer; Saturday unsettled in morning, possibly showers; fair in afternoon and cooler; fresh to possibly strong south to southwest winds.

For Lower Michigan: Showers and thunderstorms tonight and possibly Saturday morning; slightly warmer tonight in extreme east portion; cooler Saturday in west and south portion.

For the Upper Lakes: Fresh to probably strong shifting winds on Superior, mostly southerly shifting to northwest on Michigan, and southeast to south shifting to southwest on Huron tonight and Saturday; showers and thunderstorms except mostly fair Saturday on Michigan. Hoist southeast storm warning 9.00 A.M. Lake Superior east of Ashland and northern Huron and southwest warning on Michigan.

For the Lower Lakes: Increasing winds becoming fresh and possibly strong southeast to southwest by Saturday; unsettled weather with showers or thunderstorms on Ontario beginning tonight or Saturday and on Erie tonight and possibly Saturday.

FIG. 145. PART OF THE INFORMATION FOUND ON THE DAILY WEATHER MAP SENT OUT BY THE DETROIT WEATHER BUREAU, FRIDAY MORNING, SEPTEMBER 14, 1928

How many different kinds of business besides shipping would be benefited by the information given here?

the arrows attached to the circles point in the direction toward which the wind was blowing in these cities. The shaded areas indicate precipitation.

> ***Special Report.*** From your nearest Weather Bureau obtain a week's weather maps. Make a study of the changes in weather at your home during the week, as shown on the map. Note the predictions made from day to day. How did these agree with the weather which followed them?

158. Climatic conditions in relation to plants and animals. In the states of the upper Mississippi Valley the temperatures may range from 40° F. below zero on the coldest winter days to more than 100° F. on the hottest summer days. These extremes are not common, but they do occur. The range in precipitation may be from a period of many months with no rain to a month or more with daily rains (Fig. 146). A single rain may range from the slightest trace of water to a flood of several inches in a few minutes. How can plants and animals endure either the lowest temperatures or the highest? How can they live in the greatest dryness or the greatest wetness?

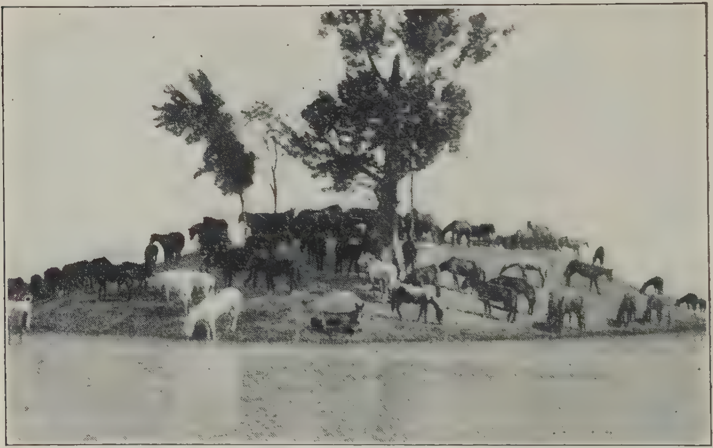

FIG. 146. MOUND AT ARCOLA, MISSISSIPPI

This was used as a refuge for farm animals during the flood of the Mississippi River in May, 1927. In how many different ways did the results of excessive rainfall affect the plants and animals in this region?

*Many of the simpler animals and many plants live a part of their lives in the form of cocoons or seeds, which can pass long periods of rest during cold weather. In this dormant[1] condition they may freeze and thaw many times without being killed, in case the temperature changes are brought about slowly.

*There are many structures and habits by means of which various animals endure the cold period or avoid it.

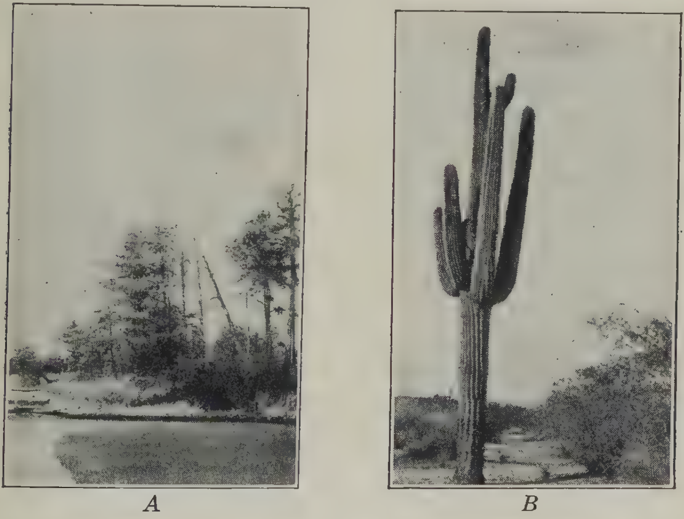

FIG. 147. PLANTS DEPEND UPON RAINFALL

A, well-watered vegetation near Phœnix, Arizona; *B*, a desert view near Phœnix (photograph by James R. Wilson). Could the plants in either of these environments survive in the other environment?

Some animals, as birds and certain butterflies, migrate[2] to warmer regions before the coldest weather has come.

159. *Rainfall and vegetation.[3] It is clear that a continued supply of water is needed not only by animals but by plants in their growing season. The total annual rainfall in various parts of the earth varies from a few inches a year to more than a hundred inches. Certain plants are able to live only where there is abundant rainfall; others can live only where there is little rainfall. Thus tropical[1] plants and those which live in or around lakes and swamps are very different from desert plants (Fig. 147). Not only are desert plants able to get along with far less water than swamp plants, but many of them are able to store up the precious water in their bodies and to give it off from their surfaces and leaves very slowly.

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[1] *Dormant* (dor′mant): in a prolonged period of rest without action.

[2] *Migrate* (mi′grate): to go to a new home in a different climate. When animals migrate they usually migrate back and forth as the seasons change. *Migration* (mi gra′shun): the journey made when animals migrate.

[3] *Vegetation* (vej e ta′shun): plant life of any sort.

> *Special Report.* Secure records of the annual precipitation for your region. Prepare a statement of the amount of precipitation for each month of the year.

160. †Evaporation, temperature, and health. When water is evaporated, heat is used to cause the forming of water vapor. If alcohol, which evaporates rapidly, is poured on the hand, a sense of coolness is produced as evaporation occurs. Try this. This is because body heat was consumed in bringing about the evaporation. Cooling of the body is commonly produced by the evaporation of perspiration. On a hot and moist day, when the air is near its saturation point, we feel hot partly because the moisture cannot evaporate and thus use some of our body heat. It used to be thought that air becomes unhealthful because of too much carbon dioxide or too little oxygen (see page 46). It is true that there might be so much carbon dioxide or so little oxygen that it would be difficult for one to secure the needed oxygen or to get rid of his undesirable carbon dioxide (see page 45). However, it is now known that such conditions are not common, and that air is more often made unhealthful by excessive humidity and high temperature than by lack of oxygen or excess of carbon dioxide. Experiments have been performed with human beings confined in glass cases in which the carbon dioxide, oxygen, and moisture content were controlled. These experiments showed that if the air is kept cool, dry, and in motion an increase of carbon dioxide above normal or a decrease of oxygen below normal causes no hardship. Hot moist air and air not in motion do soon cause discomfort which if not relieved by change of air (that is, by proper ventilation) would cause death.

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[1] *Tropics* (trop′iks): the region near the equator. *Tropical* (trop′i kl): having to do with the tropics.

161. *Effects of bodies of water on climate. Large bodies of water exert an important influence upon surrounding land. For example, in the Great Lakes region many cases are recorded where frost has occurred on the land several miles from the lakes but not near them. The water helps to keep the temperature above that at which frost occurs. Moreover, near lakes and oceans the water has a marked influence in delaying plant growth in springtime. By this means it may help to cause fruit trees to be delayed in flowering. This reduces the dangers to the plants from early frosts. In the same way bodies of water tend to reduce the high temperatures in summer. This is of value to crops in reducing the excessive evaporation which extremely hot weather may cause. There are many regions near lakes and oceans where fruits are grown successfully because of the favorable effect which bodies of water produce on the climate (Fig. 148). Thus, south and east of Lakes Michigan, Erie, and Huron there are extensive orchards and vineyards which have become famous. These may extend more than twenty miles from the lakes before getting out of the range of the water's influence. The winds which commonly come from the north across the lakes prevent the regions north of the lakes from benefiting so much from the moderating influences of the water.

These same influences of the climate near bodies of water cause the shores of lakes and oceans to be sought for use as homes and for pleasure resorts during summer.

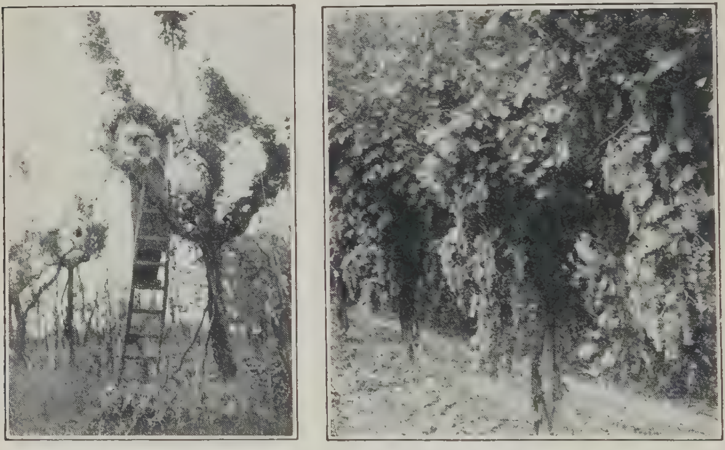

FIG. 148. GRAPE FARMING IN ITALY

The vines are pruned and trained to grow upon the stem of a small tree. The branches of the supporting tree are cut back so that just enough grow to keep the tree alive, thus not shading the grapes. At the left is an early spring view; at the right, an autumn view with a full crop of grapes. This vineyard is as far north as are parts of Montana and North Dakota. Why can grapes be grown near the Mediterranean Sea better than in Montana and North Dakota?

162. †Climate, people, and progress. The people in the very hot or extremely cold climates have never made as great progress as have the people in the temperate climates. In the tropics heavy rainfall, high temperatures, and excessive humidity produce such an abundance of plant and animal life as to make it difficult for men to build cities and other works of civilization. There is food in plenty; but the great tropical forests with their dense masses of trees, vines, and plants, and with their great number and variety of animals, many of them dangerous to man, cannot easily be conquered. Spaces in the jungles are cleared and kept clear with great difficulty because the tropical vegetation grows so rapidly.

*In the coldest climates progress is held back, but for opposite reasons. Extremely low temperatures discourage life of all sorts. There is practically no life whatever at the poles. Where men are able to live in the polar regions the vegetation is scanty, with the result that fuel and food are scarce.

Special Reports. Make a detailed study of a hot country: its location with reference to North America, Europe, and Asia, the trade routes by which it may be reached, the influence of its location upon its climate, its location with respect to prevailing winds, its position on the continent, its nearness to the ocean, its plant and animal life and how these are fitted for their environment, and the life, progress, and industries of its people. Make a similar study of a cold country.

163. Altitude, people, and progress. In the world's history it has generally been found that the people who have lived either in very low land or in very high land have made much less progress than people who have lived at moderate heights above the sea level. A reason is that the climate is likely to be less favorable to civilization in the extreme lower altitudes or higher altitudes than in the altitudes between these extremes. Progress is difficult or impossible in lowland swamps, in lowland valleys which are subject to frequent floods, or in desert lowlands which are subject to long periods without rain. Progress is likewise difficult or impossible in the high mountainous regions where the rocky hills and narrow valleys are usually unsuited to farming and to the building of cities. Moreover in high altitudes the warm season is often too short for sufficient crops to grow or for sufficient necessities of other sorts to be produced or secured to enable people to live comfortably during the long cold winters. In the tropics, however, white people commonly find the lowland climate unsuited to them. When possible, therefore, they move to the plateaus which are high enough so that their climate is like that of the middle altitudes in the temperate zones where progress has usually been most rapid.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. Weather sayings are in most cases based upon careful scientific observations.
2. Predictions by the United States Weather Bureau are based upon careful scientific observations.
3. The services of the Weather Bureau are of very great value to commerce and business.
4. Freezing kills all animals and plants.
5. Some desert plants can live where there is no water.
6. It has been suggested as a possibility that another great lake might be made by damming the Red River of the North. If this were done the winters in North Dakota would probably be more severe than they now are.
7. Few animals and plants live at the poles.
8. Man makes greatest progress in the tropical regions.

UNIT VII. BEYOND THE EARTH

CHAPTER XVI

THROUGH SPACE WITH THE ASTRONOMERS

Some Questions this Chapter Answers

Why did ancient men need to study the heavens? What is astrology, and how did it develop? How is modern astronomy related to astrology? How do the ancient and modern methods of studying astronomy differ? What are some of the marvelous facts which astronomers have learned? Does our solar system occupy a large portion of the heavens or a small portion? What are stars like? What is the Galaxy? Is there more than one galaxy in the heavens? How important a body is our earth?

164. *Men have always studied the sky. The earliest men must have studied the heavens. They needed to know something about the heavens in order to survive. Since there were no clocks, they had to judge the time by the positions of the sun during the day and of the moon and stars at night. Since they had no printed records they had to watch the sky to know when it was wise to plant and reap the crops and when it was safe to go upon hunting and fishing expeditions.

Since so much of their safety and welfare depended upon their being able to observe and interpret the positions of the heavenly bodies (Fig. 149) primitive men came to regard the heavens with awe and superstition. Some of this awe and superstition still remained after man became civilized. Even today we sometimes find ignorant people who regard with dread and fear such wonderful and beautiful phenomena as comets (Fig. 167, p. 282) and eclipses (Fig. 161, p. 270).

165. Astrology not a true science. Little by little, as men became civilized, they began to organize their scanty knowledge of the heavens into a rude sort of science. This was not at first a real science of astronomy,[1] because such astronomical facts as wise men knew were mixed with all sorts of superstitious beliefs. This mixture of a little astronomy with a great deal of superstition and fancy was called *astrology.*

Astrology was well established in the days of ancient Babylon, about 3000 B.C. It spread from Babylon throughout the ancient world. The ancient astrologers were priests who pretended to be able by studying the positions of the planets and stars to predict the will and intention of their gods.

Intelligent people in general have long ceased to believe in astrology or to regard it as a science, yet even today we occasionally find persons who claim to be astrologers. They claim to be able to study the stars and the planets and thus to be able to tell one's "past, present, and future, to advise in love, marriage, and business," and to do other impossible things (Fig. 150). Most of these

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[1] *Astronomy* (as tron′o my): the science of the stars and other bodies in the heavens. *Astronomer* (as tron′o mer): one who has a broad knowledge of astronomy. *Astronomical* (as tro nom′i kl): having to do with astronomy.

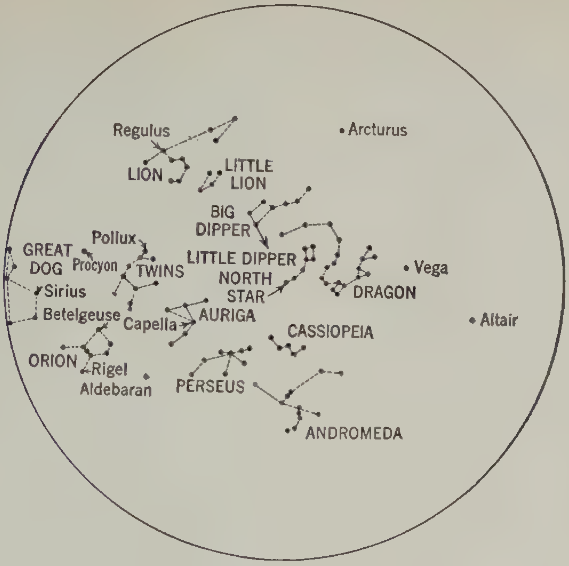

FIG. 149. MAP OF THE HEAVENS

Modified from map by Hydrographic Office, United States Navy

This map shows a few of the more familiar constellations and a few of the "first magnitude," or brightest, stars.

Project. To make a star map locating two constellations. Draw a circle with a six-inch diameter. Put a cross at the center. Label it "North Star." Write "North" at the bottom of the circle, "Overhead" at the top, "East" at the right, and "West" at the left. Early in the evening when the stars are showing, sight over a tree or the top of a chimney or house at the Big Dipper and at Cassiopeia. Carefully mark small crosses to show the exact positions of the stars in these constellations. An hour later stand in the exact spot where you stood when you first marked the positions of these stars. Again note the positions of the stars in the two constellations. Have they moved? Mark their positions now with small circles. Write on your star map the exact hours and the date of your observations.

people are "quacks," who live by use of superstitions of people who are willing to believe statements without proof.

166. Astronomy grew out of astrology. The science of astronomy owes much to the early astrologers. In their study of the sky for omens or signs bearing upon human affairs they discovered and confirmed many scientific facts. Thus astronomy slowly developed out of astrology.

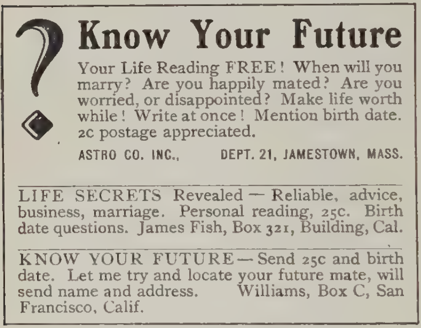

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FIG. 150. ADVERTISEMENTS OF ASTROLOGERS

Only ignorant people would believe that astrologers can "tell the past, present, and future by the stars"

Many hundreds of years before the time of Christ, the Babylonians and other ancient nations had learned to recognize five of the planets — Mercury, Venus, Mars, Jupiter, and Saturn — and had given names to the most noticeable of the constellations; but the Greeks receive credit for having made the first beginnings in a real science of astronomy, because they were the first people who tried to classify[1] the heavenly bodies and to explain the astronomical facts they found in the writings of the Egyptians, Chaldeans, and other ancient peoples.

> *Special Reports.* What astronomical knowledge was possessed by the Egyptians? the Chaldeans? the Babylonians? the ancient Chinese?

The Greeks named many of the constellations (Fig. 151)

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[1] *Classify* (clas'i fy): to arrange objects in classes; to put into classes.

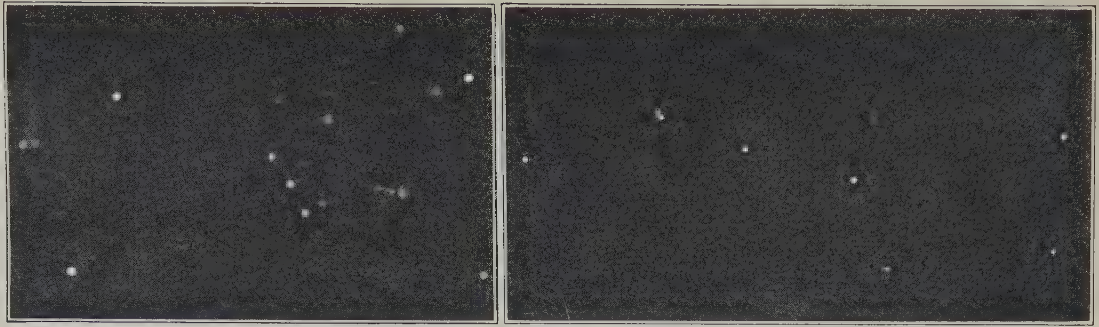

FIG. 151. THE CONSTELLATIONS OF ORION AND THE BIG DIPPER

Photograph by Yerkes Observatory

The constellation of Orion contains two first-magnitude stars. The Big Dipper is part of the Great Bear. The two stars in the front of the bowl of the dipper point toward the Pole Star. Ancient Greek myths or fables, invented to try to explain the constellations, seem to us very strange and unscientific. Here is one.

Jupiter, king of the gods, fell in love with Callisto, a nymph. Juno, queen of the gods and wife of Jupiter, became jealous of Callisto and determined to destroy her. In order to save Callisto's life, Jupiter changed her into a bear. Juno then plotted to have Diana kill the bear in the chase. To save her, Jupiter placed the bear, Callisto, in the heavens, and near her he placed her son, Arcas, as the Little Bear. When Juno learned of the honor which had been bestowed upon Callisto and Arcas, she was more angry than ever. In her desire for revenge she hastened to Oceanus, king of the ocean, and persuaded him never to allow the nymph and her son to set in the ocean like the other stars. According to this myth, this is the reason that the Great Bear and the Little Bear must always keep turning round and round the night sky without rest.

after their gods, their heroes, and various animals and creatures of their imagination. Many interesting myths[1] and legends, which attempted to explain and account for the constellations, have come down to us from the ancient Greeks (see page 249).

167. † Early astronomers had no telescopes. It is surprising how much early astronomers learned when we remember that they had to make all their observations with the naked eye. The telescope was invented only about three hundred years ago, and the spectroscope is a very recent invention. (See Chapter XXXIV for the telescope and the spectroscope.) By means of the telescope, the spectroscope, and other marvelous instruments, astronomers have been able to measure the distance to various stars, to find out the nature and the weight of the earth, the sun, and other heavenly bodies, and to determine much about the conditions which exist on the different planets.

168. Many marvelous facts learned by the astronomers. Our earth is one of a family of eight planets round the star which we call the sun. Each of these planets speeds round the sun in a great nearly circular path called its *orbit*. Mercury, the nearest, is so far from the sun that if an express train could leave the sun traveling at the rate of a mile a minute toward Mercury, it could not reach it for nearly seventy years. Neptune, the farthest from the sun, is so far away from the sun that the same train traveling sixty miles an hour would take more than five thousand years to reach Neptune.

169. *Our solar[2] system a small part of the heavens. The size of our solar system is so great that we cannot comprehend it, yet it occupies only an exceedingly small part of the space which the astronomers have explored. In fact, between our sun and the next nearest star there would be room for several thousand solar systems as large as ours. Vast as this distance is, the astronomers have been able to measure the distance to other stars which are no less than twenty thousand times as far away from our sun as is the nearest star.

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[1] *Myth* (mith): an ancient story invented to explain some phenomenon or custom.

[2] *Solar* (sō′lar): having to do with the sun (*sol* is the Latin word for "sun").

We can get an idea of the enormous distances which astronomers have measured in another way. Light travels 186,300 miles in one second; thus it travels fast enough to go more than seven times round the earth at the equator in one second. It takes the light from our sun about eight minutes to come from the sun to the earth. Light takes over four hours to come from Neptune to the earth. It takes over four years for the light to travel to us from the star nearest to our sun. The light that we are now receiving from the Pole Star started about forty years ago, and there are stars so far away that the light by which we now observe them started from them nearly a hundred thousand years ago. For all that we know, some of these distant stars may no longer exist as stars. If they had been destroyed, however, we should have no way of knowing this for thousands of years, because the light which left them before they were destroyed would still be coming to the earth.

170. Stars larger and smaller than our sun. The astronomers have learned that the stars vary greatly in size. There are suns which are no larger than the planets of the solar system. Our sun is more than a million times larger than the earth, yet it is hardly a medium-sized sun. Betelgeuse, the beautiful orange-red star in Orion (Fig. 149, p. 247), has about 27,000,000 times the volume of our sun, and red Antares may be a still larger sun. Antares is less dense than the best vacuum which we can make in the physics laboratory; but some of the smallest stars are so dense that a cubic inch of their substance would weigh a ton. Thus it would take a powerful derrick to lift a lump of this substance the size of a golf ball [1]; and a railroad flat car could hardly hold up the weight of a lump the size of a man's doubled fists!

Most of the suns are too hot to be anything but gas. Antares is a gas so light that it is less than one millionth as heavy as a globe of water of the same size would be. The sun is one and a half times as heavy as the same volume of water would be. Some of the smallest suns are solid and weigh many thousand times as much as the same volume of water would weigh.

171. The Milky Way made up of billions of stars.[2] When we look at the sky on a clear night when the moon is not shining, we see a broad band of dim light stretching across the heavens. We call this band of light the Milky Way, or Galaxy. When we examine the Galaxy with a small telescope we find that the dim light is really the light of separate stars so close together that we cannot see them as separate stars with the naked eye. Our small telescope reveals several hundred thousand stars in the Galaxy; with the greatest modern telescope (that on Mt. Wilson, California) more than a *billion* may be photographed (Fig. 152). Astronomers believe that there are probably innumerable suns in our galaxy which even the monster telescope does not reveal, because their light is too dim or because they are dark. Doubtless hundreds of thousands more would be revealed by more powerful telescopes.

---

[1] A golf ball is 1.62 inches in diameter.

[2] *Billion* (bil'yun): a thousand million.

Astronomers know that our sun is merely one of the smaller stars in the Galaxy. If the whole Galaxy could be seen at once, it would be found to be an enormous swarm of suns grouped together somewhat in the shape of a watchcase (Fig. 169, p. 290). All these suns are moving in response to the gravitational attraction (see page 110) of other stars in the group. They are traveling in various directions like a swarm of insects, at the average rate of about half a billion miles a year. They are so far away that from year to year we can observe no changes in their positions; in fact, if we could have seen the sky at the time of Christ it would have looked almost exactly as it does now.

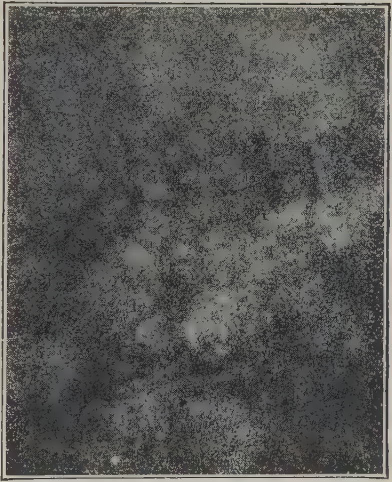

FIG. 152. STAR CLOUDS IN THE MILKY WAY

Every white dot is a sun. These suns are actually trillions of miles apart. (Courtesy of Yerkes Observatory)

172. Many galaxies in the heavens. The galaxy which we see in the sky is brighter than other portions of the heavens, because we are looking through that part of it which is greatest in extent and where the stars are thickest. Moreover, these stars are not close together, as they seem to be. They are, in fact, thousands of billions of miles apart. Furthermore, the galaxy of which our sun is an unimportant member is only one swarm of stars. There are hundreds of thousands of luminous[1] cloudy patches called nebulæ (Fig. 169, p. 290) scattered through the heavens. Many of these are distant galaxies containing billions of suns. Some of these galaxies are probably smaller than ours and others are even larger.

173. Probably few suns have families of planets. Astronomers have never yet found any evidence which would lead them to believe that any other star besides our sun is surrounded by a group of planets. In fact, there are reasons to believe that if there are any other suns surrounded by planets these suns must be exceedingly rare. Furthermore, we have no way yet of discovering any of these planets if they do exist, because if a planet as great as Jupiter, the largest in our solar system, circled round the nearest star beyond our sun, it could not be seen with the most powerful telescope.

174. Our earth of small importance in the heavens. Our earth seems to us vast and important. However, it is just a tiny speck in comparison with our sun, which is only a medium-sized star and one of perhaps ten billion in the Galaxy, and there are hundreds of thousands of other galaxies, or star systems, scattered through space with the distances that separate them so great that our minds fail to comprehend them. We are forced to realize that our earth and ourselves and even our solar system are so small as to be of little importance. Yet we can be proud of the fact that, small as we are, the minds of our scientists have been able to invent instruments which have enabled them to explore these vast heavens and to tell us with assurance about so many of the marvels that the heavens contain.

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[1] *Luminous* (lu′mi nus): giving off light.

TESTS AND GUIDES FOR STUDY AND REVIEW[1]

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. Astronomy grew out of ----, which is not a true ----.
2. Two instruments of very great importance in the study of astronomy are the ---- and the ----.
3. Our solar system occupies a very large portion of the heavens.
4. The nearest star to the earth is ----.
5. Light travels ---- miles per second.
6. The sun is a medium-sized star.
7. The Milky Way, or Galaxy, is composed of probably many million stars.
8. Astronomers believe that there are hundreds of thousands of galaxies, each of which contains billions of suns.
9. Many other stars besides our sun are known to be surrounded with families of planets.

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[1] Some of these statements are based on paragraphs which are not starred.

CHAPTER XVII

THE SOLAR SYSTEM

Some Questions this Chapter Answers

What bodies are included in the solar system? What are the characteristics of our sun? In what respects are the planets alike? In what respects do they differ? What are the characteristics of our moon? What causes the phases of the moon? How are eclipses caused? What causes the tides? Are there people on Mars? What and where are the asteroids? What are the characteristics of comets? What are meteors and meteorites? How do scientists believe the solar system was formed?

175. *What "solar system" means. Our solar system consists of our sun and all the heavenly bodies of various kinds that revolve round it. These bodies are the eight planets with their satellites (moons), the asteroids (sometimes called planetoids), the meteors and meteorites, and the comets.

* Each of these bodies follows an orbit, or path, round the sun. They are held in their orbits by gravitational attraction, which tends to pull them in toward the sun. If it were not for this attraction the inertia (see page 107) of the swiftly moving planets would cause them to travel straight away, never to return. These orbits are so exact and definite that after a few observations of a planet, moon, asteroid, or comet the astronomers are able to

compute the entire orbit of the body and to determine with great accuracy where that body will be at any future date.

Experiment 34. What is the shape of a planet's orbit? Through the middle of an old rubber ball or tennis ball stick a darning needle just a little longer than the diameter of the ball, so that about a quarter of an inch of the needle projects through the ball on each side. Make a rubber string two or three feet long by tying rubber bands together or by doubling a section of the rubber winding of the core of a golf ball. Wind this string *tightly* round the ends of the needle back and forth several times, leaving the end of the string projecting from the middle of the ball between the ends of the needle (Fig. 153). As you whirl the ball round your head it will take a circular path if you keep it traveling at the same speed, but will take an ellipti-

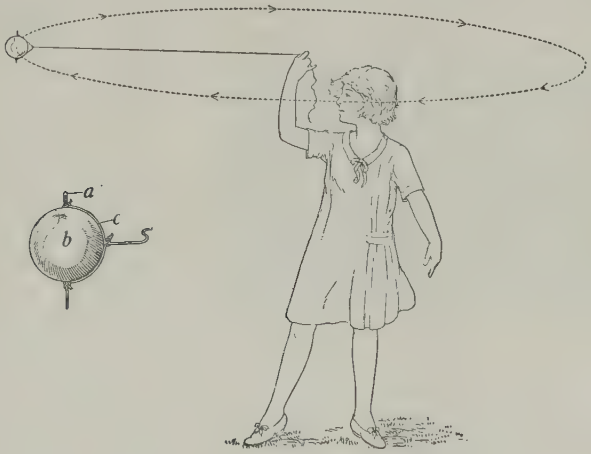

FIG. 153. THE SHAPE OF AN ORBIT

An experiment to show the shape of the orbit of a planet, an asteroid, or a moon: *a*, darning needle; *b*, tennis ball; *c*, rubber string cal path (Fig. 191, p. 335) if you make it go faster in one part of its orbit than in another (Fig. 153). Answer with a complete sentence the question asked at the beginning of this experiment.

176. *Our sun. The sun is a ball of incandescent gas about 865,000 miles in diameter. It rotates (spins on its axis[1]) faster at the equator than near the poles, requiring about twenty-five days at the equator and about thirty days near the poles. The temperature at its surface is perhaps as high as 10,000° F., which is much greater than any temperature that has yet been produced on the earth. It is believed, moreover, that toward the middle of the sun the temperature is enormously hotter than at the surface. Around the sun is an atmosphere of incandescent gases many thousands of miles deep.

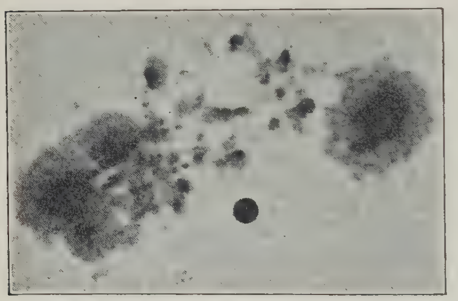

FIG. 154. A GROUP OF SUN SPOTS

The round black spot is drawn in the photograph to show the size of the earth compared with these sun spots. (Courtesy of Mt. Wilson Observatory)

As we observe the sun through a powerful telescope we are able to learn many facts of great interest. Here and there we see dark spots ranging from a few miles to many thousands of miles across. These are called sun spots (Fig. 154). Sun spots are violent storms resembling enormous tornadoes (see page 219), caused probably by eruptions[1] from beneath the sun's surface. Sun spots may disappear in a few days or they may last for months. We find other evidence of storms on the sun. Masses of matter many times larger in volume than our earth are blown across the face of the sun at the rate of hundreds of miles a minute as if by a violent wind. As we watch we see other equally vast masses of matter hurled upward hundreds of thousands of miles away from the surface as if by explosions (Fig. 155).

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[1] *Axis* (ax′is): the line which is imagined as passing through a spinning body, and upon which the body turns.

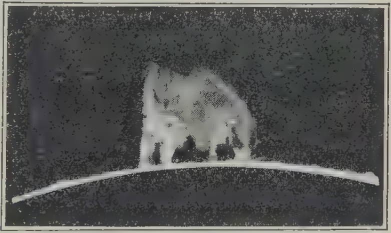

FIG. 155. AN EXPLOSION AT THE SUN'S SURFACE

This prominence or explosion is called the "Woolly Elephant" because of its shape. The earth would look like a small dot beside this prominence. (Courtesy of Yerkes Observatory)

Exchanging our telescope now for a spectroscope, we are able to learn still other interesting facts about the sun. We find that it is made up of many of the elements found on the earth. The nature of nearly sixty of these solar elements has been determined. These are chiefly metals and the gases hydrogen and helium. No gold, platinum, or mercury have yet been discovered in the sun; nevertheless these heavier elements may exist there, but so far inside that light from them does not reach the sun's surface.

We can get a faint idea of the sun's energy when we consider that all the energy which the earth receives from it is only about one part in every two billion of the energy which the sun is constantly radiating (see page 164) off into space. Yet without this energy, life on the earth would be impossible, for we should have no green plants and consequently no food, no winds and rains and consequently no rivers and streams. Why?

---

[1] *Eruption* (e rup'shun): a violent pouring out of matter, as from a volcano (Fig. 22, p. 49).

177. *The planets. There are eight known planets in our solar system. They may be distinguished from the stars because (1) they shine with a steadier light and (2) from night to night they change their positions among the stars. We can see them because, like the moon, they reflect the sunlight. These planets, named in the order of their distances from the sun, are Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus, and Neptune (Fig. 156). The four nearest the sun are called the terrestrial planets; the four farthest from the sun are called the great planets. The terrestrial planets are small, solid, and several times heavier, volume for volume, than water. The great planets are many times larger than the terrestrial planets (Fig. 156), and probably all of them are entirely gaseous. Jupiter, Uranus, and Neptune are slightly heavier, volume for volume, than water, but Saturn is lighter; that is, it would float if there were an ocean big enough to hold it. None of the planets is a perfect sphere; all are slightly flattened at the poles — the great planets more so than the terrestrial, and Saturn most of all. All follow definite paths, or orbits, round the sun. All travel in their orbits from west to east (Fig. 191, p. 335). Their

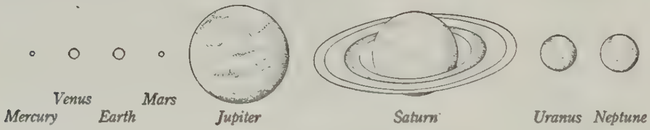

FIG. 156. DIAGRAM SHOWING THE RELATIVE SIZES OF THE EIGHT PLANETS OF THE SOLAR SYSTEM

orbits are almost perfect circles, that of Neptune being most nearly perfect, and are all in nearly the same plane.

The earth, Mars, Jupiter, and Saturn rotate in the same direction that they revolve round the sun — from west to east; Uranus rotates in the opposite direction — from east to west. Mercury and Venus are the only planets which have not at least one satellite, or moon; nearly all of the other planets have more than one moon.

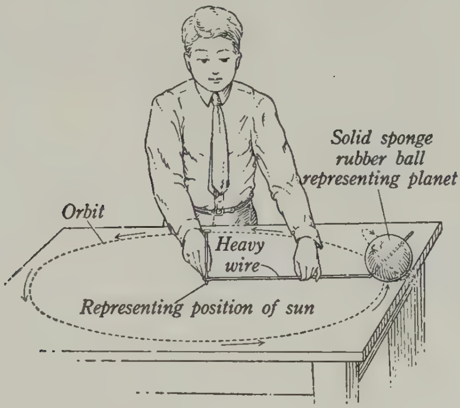
Solid sponge rubber ball representing planet
Orbit
Heavy wire
Representing position of sun

FIG. 157. ROTATION AND REVOLUTION OF A PLANET

Since the ball in this model revolves from east to west, it must represent which one of the planets?

Project. To make a model illustrating the rotation of a planet on its axis and the revolution of the planet in its orbit round the sun. Bend a heavy wire as in Fig. 157. Use a rubber ball or tennis ball to represent the planet. Hold the free end of the wire firmly while you move the "planet" end round it in a circle to represent the orbit. Keep the "planet" against the table top so that it will rotate as it revolves round the "sun."

Some astronomers believe it possible that there may be still other planets which revolve round our sun but at distances so great that they have not yet been discovered.

It will help you to get a mind picture of the solar system if you think of the sun as a ball 5 feet in diameter. On this same scale, then, Mercury would be represented by a tiny ball about one fifth of an inch in diameter, over 200 feet from our five-foot sun; Venus, by a marble about half an inch in diameter, nearly 380 feet away; the earth, by another half-inch marble, over 500 feet away; Mars, by a tiny ball about three tenths of an inch in diameter, more than 800 feet away; Jupiter, by a ball half a foot in diameter, over half a mile away; Saturn, by a five-inch ball, nearly a mile away; Uranus, by a two-inch ball nearly 2 miles away; and Neptune by a ball one and four-fifths inches in diameter, over 3 miles away from the five-foot sun.

178. *Mercury. Mercury is not only the nearest planet to the sun but is also the smallest and the swiftest-moving. It is only about 3000 miles in diameter and is about 36,000,000 miles from the sun. Its orbit is less like a perfect circle than that of any of the other planets. It is difficult to see, because one has to look in the direction of the sun to see it.

*Mercury revolves round the sun in eighty-eight days. It is practically certain, moreover, that it always keeps the same side toward the sun. If this is true, the side which is always in the sunlight is hot enough to melt lead, whereas the dark side is always very cold. Mercury has no atmosphere and no moons, probably because, being so small, it has not sufficient gravitational attraction to hold either an atmosphere or a satellite.

> Give reasons why if Mercury rotates only once in eighty-eight days, its side next to the sun is very hot.

179. *Venus. Venus is often called the earth's twin because it is almost as large as the earth and because the conditions existing on it are more like those on the earth than on any other planet. It has an atmosphere probably about as dense as ours, but more cloudy.[1]

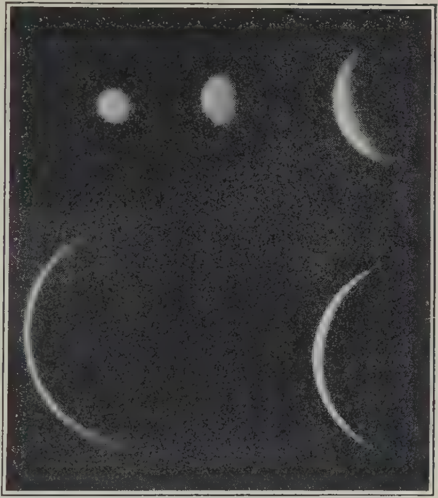

FIG. 158. THE PHASES OF VENUS

In the top left-hand picture Venus is on the opposite side of the sun from the earth. In the bottom left-hand picture Venus is on the same side of the sun as the earth and almost between the sun and the earth. Can you diagram the positions of the earth, Venus, and the sun when Venus looks largest and when it looks smallest? (Photograph by E. C. Slipher, Lowell Observatory)

*Venus requires two hundred twenty-eight days to travel entirely round its orbit. This planet probably takes several weeks, perhaps even months, to rotate on its axis. One side is therefore very hot and the other side very cold. There would not be so much difference between the temperatures of the two sides as on Mercury, because Venus is farther from the sun and because of its atmosphere.

How does the atmosphere on the earth and on Venus help to keep the temperature more even? Storms more violent than any we know of on the earth are probably constantly passing between the hot and the cold side of Venus. Remembering the cause of land and sea breezes (see page 215), can you explain (1) whether these gales would blow from the warm to the cold side, or the opposite; (2) why these gales should be so violent? Venus approaches closer to the earth than almost any other heavenly body except the moon, but we cannot study Venus when it is nearest, because we cannot see it. If there are intelligent beings on Venus they have their best view of the earth at this time (Fig. 158). Can you explain these statements?

---

[1] *Cloudy* (kloud′y): filled with clouds.

Next to the sun and moon, Venus at its brightest is the brightest object in the heavens (Fig. 158). For several months it appears in the west as the evening star, then is not seen again for a few weeks, after which it appears in the east as the morning star.

180. *The earth. The earth is the largest of the four terrestrial planets (Fig. 156, p. 260). It is about 8000 miles in diameter and 25,000 miles round at the equator. The atmosphere surrounding the earth is as much a part of it as are the oceans and the land. The interior of the earth is very hot; yet it is not soft like pitch, but rigid[1] like steel.

To those of us who are familiar with mountains the earth's surface seems very uneven and rugged, just as the tiny pebbles and mounds on the ground may seem enormous to small insects; yet if the earth, which seems so great and important to us, were reduced to the size of an orange, it would be smoother than the orange skin, and if it could be viewed from the sun, it would look like a tiny speck.

*The earth rotates on its axis once in twenty-four hours and makes a complete revolution through its orbit round the sun in $365\frac{1}{4}$ days. Its axis is not perpendicular to the plane of its orbit round the sun (Fig. 191, p. 335), but tilts at an angle of $23\frac{1}{2}$ degrees from this perpendicular. Our seasons are due to this tilt of the earth's axis, as will be explained in Chapter XX.

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[1] *Rigid* (rij′id): not easily changed in form.

181. *The moon's surface very uneven. Our moon is about 2100 miles in diameter. It is about 240,000 miles from the earth. When we look at it, even without a telescope, its surface appears to be very rugged and uneven. With a good telescope we can see clearly what its surface is like.

Unlike the surface of the earth, great areas of the moon's surface are dotted with thousands of round depressions, or pits, which look like the craters[1] of enormous inactive volcanoes (Fig. 159). Some of these are many times larger than any volcanic craters on the earth. These depressions are usually called lunar craters or moon craters. It is not known, however, that they were formed by volcanoes. The largest of them are perhaps a hundred miles in diameter, but most of them are less than three miles

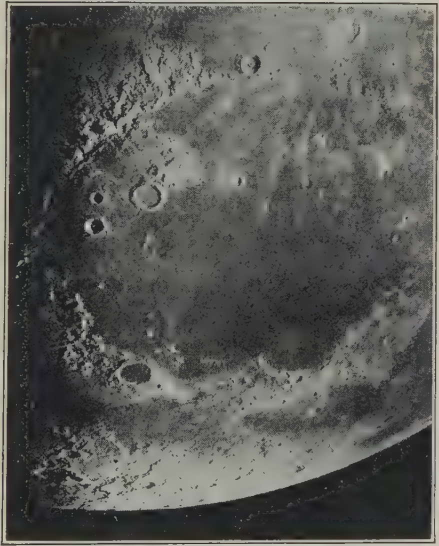

FIG. 159. PHOTOGRAPH OF THE SUNSET AS IT APPEARS ON THE NORTHERN PORTION OF THE MOON

Courtesy of Mt. Wilson Observatory

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[1] *Crater* (kra′ter): the chimney-like opening in a volcano.

deep. Often other craters will be found in a large one, or perhaps a single mountain will tower a mile or more into the air from the floor of one large crater.

*Besides these crater-like depressions, the moon has mountain chains much like the mountain chains on the earth, with towering peaks like church spires nearly as high as Mt. Everest. Not all the moon's surface is rugged. Parts of it are great smooth areas with only here and there a crater or a single slender peak.

From some of the largest lunar craters light-colored streaks extend in many directions for great distances; one is nearly two thousand miles long. In Fig. 2, p. 7, these streaks may be seen extending from Tycho, the great crater shown near the top of the picture, and also from some of the other craters. Apparently these streaks are neither higher nor lower than the surrounding surface, but run in very straight lines across the pitted lunar landscape. No scientist has yet been able to explain satisfactorily what the streaks are or what caused them, though some astronomers think that they were caused by the staining of the lunar surface by gases escaping from inside the moon. In addition to these streaks, the lunar surface has numerous huge cracks called clefts or rills. Although these are sometimes more than a hundred miles long, they are usually very narrow, perhaps not more than half a mile or so wide. From century to century the surface of the moon remains unchanged except for such slight changes as may be caused by falling meteors and meteorites.

182. †Other features of the moon. The moon always keeps the same side toward the earth. The lunar orbit is not in the same plane as the earth's orbit; therefore the moon swings above and below the earth, giving us a glimpse of more than half its surface. It is probable that we shall never see the rest of its surface, but there is no reason to believe that it is very different from the part that we have seen.

†The moon has no atmosphere, no water, and no life of any sort. In the sunshine on the lunar surface the temperature is doubtless as high as the boiling temperature of water, but a short distance away in the black shadow it is far below the freezing point of water. These great differences of temperature are due to the fact that there is no atmosphere to hold and distribute the heat. For the same reason the temperature during the lunar night, which is two weeks long, may fall almost to absolute zero, the coldest temperature possible anywhere.

If it were possible for one of us to be on the moon, he would be able to travel about very swiftly, because the gravitational attraction at the surface of the moon is only about one sixth that on the earth. This statement means that a man weighing one hundred and eighty pounds on the earth would weigh only about thirty pounds on the moon; therefore if he could jump five feet on the earth, he could just as easily jump about thirty feet on the moon.

If one could look from the moon he would see the stars shining brilliantly in a black sky. These stars would be visible during both the lunar day and the lunar night. He would see the earth, bright in its reflected sunlight, looking like a huge almost motionless disk in the sky, about four times as wide as the moon looks to us. He would be able to see its oceans and continents spin by as it makes its daily rotation, and would even be able to observe its clouds and storms.

* The moon revolves round the earth in twenty-nine and one half days. Since the moon always keeps the same side toward the earth, the sun shines on every part of its

surface during the moon's complete revolution round the earth. Daylight on any part of the moon, therefore, would last about fourteen of our days, and darkness the same length of time.

183. *Phases of the moon. The moon is not incandescent like the sun: it shines, like the planets and the asteroids, by reflected sunlight. We know from watching it that it sometimes looks like a thin crescent and sometimes like a round golden disk, as Venus looks in Fig. 158, p. 263. The differences in the appearance of the moon during the month are called the phases of the moon. When the moon is at the point in its revolution where it is between the earth and the sun, the illuminated[1] side is away from the earth. We can see only a tiny bright crescent in the western sky with its points toward the left. As the moon revolves we are able to see a little more of the lighted half each night. After seven days we are able to see half the lighted half, or one quarter of the moon's surface. We call this the first quarter. Slowly, as the moon revolves in its orbit, we are able to see more and more of the lighted half until, seven nights after the first quarter, we can see the entire lighted half. We call this full moon. After full moon the moon begins to "wane"; that is, we are able to see less of the lighted half each night until seven nights after full moon, when we can again see only half the lighted half. We call this the third quarter. During the next seven days the crescent which we can see becomes smaller and smaller, with its points toward our right, until it disappears at new moon. The phases are then repeated.

Experiment 35. How can you represent the phases of the moon? Take a basket ball to represent the moon and a floor lamp across the room to represent the sun. Let your head represent the earth. Hold the basket ball a little higher than your head in the line between you and the lamp (Fig. 160). This position represents new moon. Slowly turn round toward your left and note how the crescent of the lighted side grows. Revolve the ball one fourth the way round. How much of the lighted half can you see now? How much of the lighted half can you see when you are halfway round? three fourths the way round? all the way round?

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[1] *Illuminate* (il lu′min ate) or *illumine* (il lu′mine): to light up.

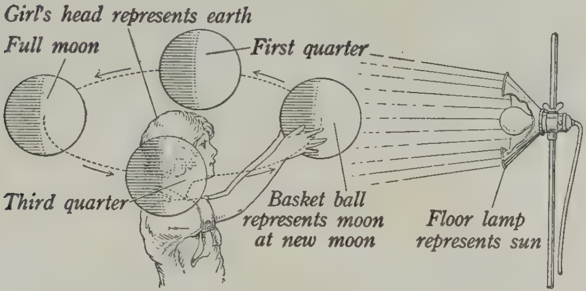
Girl's head represents earth
Full moon
First quarter
Third quarter
Basket ball represents moon at new moon
Floor lamp represents sun

FIG. 160. REPRESENTING PHASES OF THE MOON

Draw a diagram showing the position of the earth, Mercury, and the sun when Mercury is nearest the earth.

184. *Eclipses. Both the earth and the moon cast cone-shaped shadows, because the sun is so much larger than they are. Sometimes at new moon the moon is exactly between the sun and the earth and near enough so that the tip of its cone-shaped shadow passes across the surface of the earth (Fig. 161, *A*). If we happen to be inside the tip of the shadow we cannot see any of the sun, because the moon shuts off our view. We call this a *total eclipse* of the sun (Figs. 161, *A*, and 162). If we are not in the cone shadow but still in the partial shadow, we can see only part of the sun. This is called a *partial eclipse* of the sun. Sometimes when the moon is between the sun and the earth the moon is too far away for the cone shadow to reach the earth's surface. This is because the earth is not quite in the center of the moon's orbit. Consequently we are not conscious that an eclipse is taking place, because the sunlight is not dimmed, but with a telescope we should be able to see the bright ring of the sun surrounding the dark disk of the moon (Fig. 162).

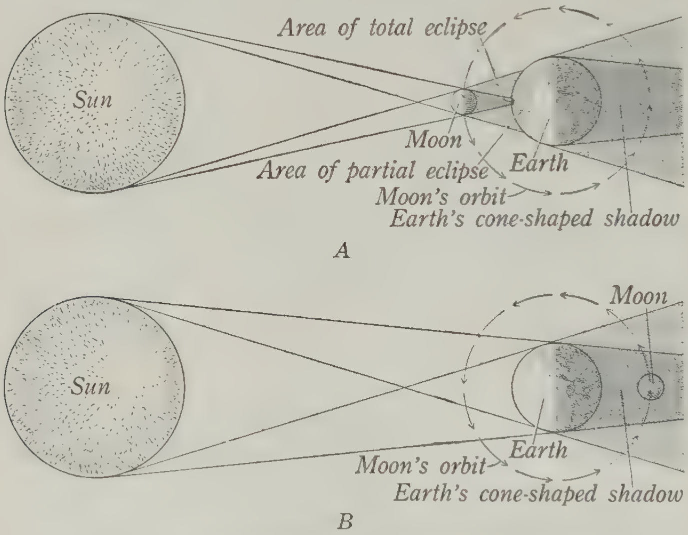

FIG. 161. DIAGRAMS SHOWING HOW ECLIPSES OF THE SUN AND THE MOON ARE CAUSED

From earliest times solar eclipses have been regarded with superstition, as they are even yet by some ignorant people. Yet their cause was at least partly understood many centuries ago. More than two thousand years before Christ two official Chinese astronomers, Hsi and Ho,

FIG. 162. A TOTAL ECLIPSE OF THE SUN

Courtesy of Van Vleck Observatory

To observe a total eclipse of the sun is a rare and wonderful event, experienced by few people, because the path of complete shadow is only a few miles wide. Through heavily smoked glass we watch the sun from the time the disk of the moon first is visible as a dot on the sun's rim. Slowly the moon's disk passes across the face of the sun, but the sunlight does not begin to get dim until most of the sun is covered. The sunlight through the branches of trees throws crescent-shaped spots of sunlight on the ground — not round spots such as we usually see. Shortly before the sun disappears behind the advancing moon, a white sheet placed on the ground shows wavering bands of light and shadow. Lovely soap-bubble colors are seen in the sky near the sun. Finally we notice that the light is beginning to grow dim. Birds and chickens seek their perches, as if evening were approaching. We see the moon's shadow racing toward us at enormous speed along the ground from the west. It reaches us at the same instant that we see the sun's disk entirely covered. The light is now a strange pale twilight. This lasts from less than one minute to occasionally more than seven minutes. During this time one can see perhaps a flaming red prominence somewhere round the edge of the sun's disk, while all round the sun is the beautiful pearly light, called the corona, from the sun's atmosphere. Stars twinkle brightly in the darkened sky. Slowly the moon passes entirely across the face of the sun and the normal daylight returns, with nothing left to indicate that an eclipse has occurred.

were executed because they failed to predict the solar eclipse and to perform the usual rites during it.

*Whenever the moon passes into the cone shadow of the earth we have a total lunar eclipse (Fig. 161, *B*). Since the moon has no light of its own, it becomes almost invisible when the earth shuts off from it the direct rays of the sun.

> Lunar eclipses can occur only at full moon, and solar eclipses only at new moon. Why? Nobody ever saw a solar eclipse at night or a lunar eclipse during the day. Why? Solar eclipses are actually more frequent than lunar eclipses, yet more people have observed lunar eclipses than have observed solar eclipses. Why?

185. *The tides. Those who live near the ocean know that the water edge keeps changing its place. They know that the water line moves gradually farther toward the land for about six hours, then slowly moves farther out for the next six hours. This movement of the water is called the tide. In some places the water line may be more than a quarter of a mile farther in at high tide than at low tide.

*The moon is the chief cause of the tides, though the sun also is a less important cause. The gravitational attraction of the earth and the moon tend to pull the two bodies together, and centrifugal force (see page 108) tends to throw them apart out of their orbits. These two forces exactly balance each other at the centers of the earth and the moon, so that they neither fall together nor fly apart. There is also centrifugal force at the earth's surface due to its rotation. On the side of the earth nearest the moon the gravitational attraction is stronger than the centrifugal force due to rotation; on the side of the earth farthest from the moon the centrifugal force is stronger than the gravitational attraction. The result is that these two forces tend to make the earth bulge[1] on the side nearest the moon and on the side opposite the moon. The solid earth is too rigid to bulge, but the water is not. Consequently there are two bulges of water under the moon, on opposite sides of the earth (Fig. 163).

*As the earth rotates these bulges follow the moon as two large waves. The result is that places on the ocean shore have a high tide every time one of these two waves reaches it and a low tide in between two high tides. Because the moon revolves in its orbit while the earth is rotating, these tidal[2] waves do not travel round the earth in exactly twenty-four hours, but take twenty-four hours and fifty-two minutes. Hence each place on the ocean

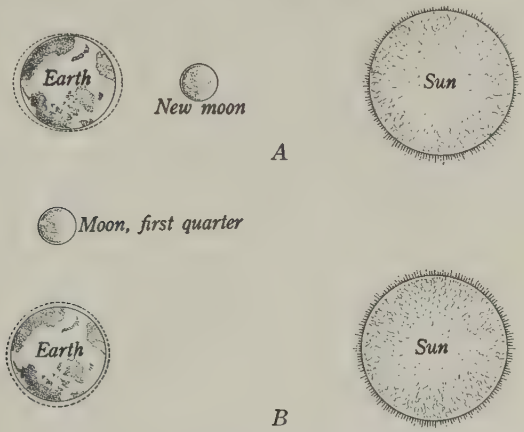

FIG. 163. DIAGRAM SHOWING CAUSE OF SPRING TIDES AND NEAP TIDES

Spring tides occur at new moon. At what other phase do they occur? Neap tides occur at first quarter. At what other phase do they occur?

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[1] *Bulge* (bulj): to swell out.

[2] *Tidal* (tī′dl): having to do with the tides.

shore has one high tide and one low tide every twelve hours and twenty-six minutes.

*At new moon and full moon, when the sun and the moon are in the same straight line, the high tides are highest and the low tides are lowest. These new-moon and full-moon tides are called *spring tides* (Fig. 163, *A*), though the name has nothing whatever to do with the seasons. At first and third quarters, when the sun and the moon are exerting their gravitational attractions in opposite directions on the oceans, the high tides and low tides are smaller than at any other times during the month. These small tides are called *neap tides* (Fig. 163, *B*).

*The tides are of great importance to ocean travel, since large vessels can enter and leave many of the ports only at high tide. The tides sometimes affect ocean travel by digging out channels into bays and river mouths and by filling others with sand and sediment. This makes constant dredging[1] necessary to keep the channels clear (Fig. 360, p. 653). The tides are also important to various fishing industries, particularly the gathering of oysters, clams, and other shellfish along the shores. They also keep the beaches clear of garbage[2] and wastes by washing the shores twice a day. In some places in western Europe the energy of the tides is used to turn small mills for grinding grain. At the mouth of the river Seine a few large power plants change the tidal energy into electrical energy. Engineers have not been able to plan a way to make use of the three-to-six-foot differences which exist in most places between high and low tides. These tides seem to be a possible future source of useful energy.

---

[1] *Dredge* (drej): to remove deposits of mud and other materials from a channel.

[2] *Garbage* (gar′baj): waste materials from the kitchen and table.

†The tidal waves must not be confused with earthquake waves, which are frequently incorrectly called tidal waves. They must also not be confused with the ordinary waves which are always found in the oceans and great lakes. The earthquake waves are caused by earthquakes and volcanic action; the ordinary waves are chiefly due to friction caused by the wind sweeping over the surface of the water.

186. *Mars. Mars is the terrestrial planet farthest from the sun. With the exception of Mercury, Mars is the smallest of the planets. It is about four thousand miles in diameter. It rotates on its axis in twenty-four hours and thirty-seven minutes, and makes one revolution round its orbit in six hundred eighty-seven days. Unlike our earth's surface, the surface of Mars is believed to be chiefly land and relatively flat. If it has oceans they are probably small and shallow. The planet has a reddish[1] color which is thought to be due to great expanses of desert. With a telescope one can see here and there green patches which may be marshes or vegetation. White spots at the poles (Fig. 164), increasing in winter and decreasing in summer, are thought to be polar ice caps similar to those on the earth.

*Mars has two tiny moons less than ten miles in diameter. It is believed that Mars has an atmosphere. If it has, this atmosphere is not so dense as is that of the earth. Because this blanket of air is so thin the temperature of Mars changes very rapidly. Temperature differences between day and night, therefore, are much greater than on the earth. In fact, after sunset the temperature at the poles may fall to 100 degrees below zero Fahrenheit.

---

[1] *Ish* on the end of a word means "somewhat," or "tending toward." Thus, *reddish* means "tending toward red"; *sweetish* means "somewhat sweet."

The climate of Mars is much cooler than that on the earth, because Mars receives less than half as much light and heat from the sun. Why?

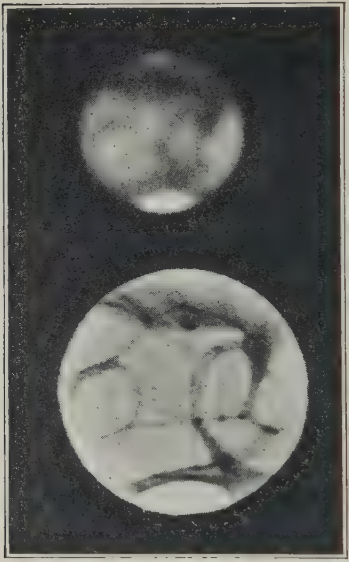

FIG. 164. MARS

The upper picture is a photograph of Mars taken through a telescope in May. Note the north polar snow cap at the bottom. The lower picture is a photograph of a drawing of Mars as one observer saw it through a telescope. Note the "canali" in both pictures. (Photographs by E. C. Slipher, Lowell Observatory)

*In 1887, when it was the custom to call some broad spots on Mars "seas," an Italian astronomer announced that he had discovered faint lines connecting the "seas." He called these *canali*, meaning "channels"; but when his report was translated into English the word was unfortunately translated as "canals." Many astronomers have since observed these lines, but many others have not succeeded in seeing them at all, and doubt that they exist. It is thought by some that these *canali* mark the courses of great irrigation ditches which intelligent beings have built to convey water from the melting snows at the poles. Others think that the larger ones are natural reservoirs or marshes which are fed by storm winds from the poles. It is possible, of course, that there may be creatures living on Mars and that they may have intelligence like that of people on the earth. No scientist, however, would state that these creatures exist or, if they do exist, that they are *people* or are *like us*. In fact, the astronomers are not agreed that they have yet discovered anything on Mars which *proves* that there is any life of any sort on it other than vegetation.

> State as many reasons as you can why it would be possible for *some sort* of creatures to live on Mars. State as many reasons as you can why it would be impossible for people *like ourselves* to live on it.

187. The asteroids. Before the year 1801 astronomers had searched in vain for some sort of planetary body in the vast space between the orbits of Mars and Jupiter. On January 1, 1801, an Italian astronomer, Piazzi, discovered in this region of the heavens a little globe only about four hundred miles in diameter which he named Ceres. Since then other smaller globes have been discovered there, one by one, until now more than a thousand of these asteroids are known. Most of them are very small, perhaps not more than twenty-five miles in diameter. It is probable that there are many others too small to be seen with the telescope. Each has its own orbit round the sun just as the planets do, and makes a revolution in from three to seven years. The orbits vary from almost perfect circles to ellipses much longer than they are wide.

Although all the planets travel round the sun in nearly the same plane, the orbits of some of the asteroids tip at a sharp angle to this plane. Most of the asteroids, those with the nearly circular orbits, are between Mars and Jupiter, but those with the elliptical orbits do not remain in this space. Tiny Eros, for example, passes closer to the earth than any other known celestial body except the moon. None of the asteroids has an atmosphere. They are thought to have very rugged surfaces and may be considered to be merely huge rocks.

> Can you think of a possible reason why none of the asteroids has an atmosphere?

188. *Jupiter. Jupiter is by far the largest of the planets of our solar system (Fig. 165). It is about eighty-seven thousand miles in diameter—so large, indeed, that if all the other planets and their satellites could be rolled into a ball, this ball would still be smaller than Jupiter. Jupiter rotates on its axis in about ten hours. It revolves round the sun in about twelve years. It has a very cloudy atmosphere; in fact, some of the huge belts of clouds above its equator are as large as our whole earth.

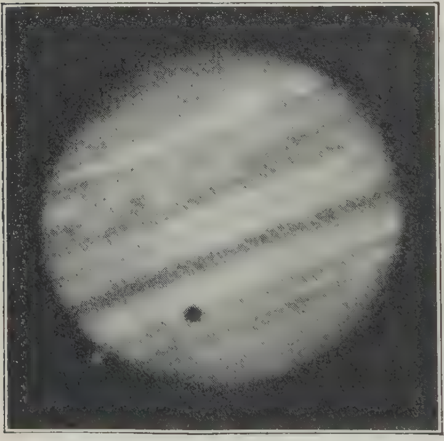

FIG. 165. JUPITER AND GANYMEDE

The white spot just below and to the left of Jupiter is Ganymede. The black spot on Jupiter is Ganymede's shadow caused by the sunshine. (Courtesy of Mt. Wilson Observatory)

Jupiter has a family of nine satellites, or moons. Four are visible with a small telescope. Ganymede (Fig. 165), the largest, is about halfway between Mercury and Mars in size. The moon nearest Jupiter requires about eighteen hours to revolve in its orbit; the one farthest away requires nearly seventy days. Two of Jupiter's satellites revolve from east to west; the rest revolve in the usual west-to-east direction.

Seen without a telescope, Jupiter shines with a steady white light. It is more brilliant than any of the stars except the sun, but is not so bright as Venus at its brightest.

> Jupiter with its moons is often compared with our solar system. In what ways is it like our solar system? In what ways is it different?

189. *Saturn. Saturn is somewhat smaller than Jupiter, but it is like Jupiter in having belts and a cloudy atmosphere. Like Jupiter it rotates on its axis in about ten hours.

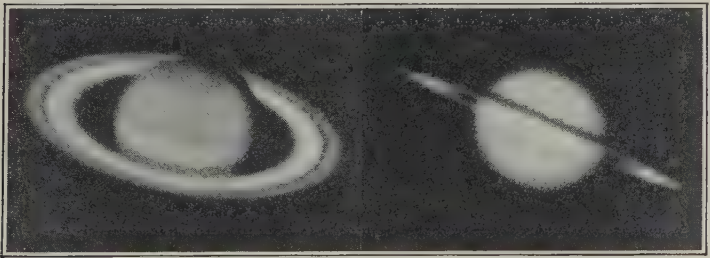

FIG. 166. TWO VIEWS OF SATURN TAKEN ABOUT SIX YEARS APART

You can see all three rings in the left-hand picture. The inner ring can only be seen against the ball of Saturn. (Photograph by E. C. Slipher, Lowell Observatory)

*When viewed without a telescope Saturn is not especially interesting. It glows with a dull yellowish light and is only as bright as a star of the first magnitude. But seen through a telescope it is glorious. It is surrounded by three rings (Fig. 166). We can easily see a bright outer ring, with a space between it and another broader, still brighter ring. If our telescope is powerful enough we can see a third, dim ring inside the second one. These rings are composed of swarms of tiny satellites, probably not bigger than meteors, which revolve round Saturn like any other satellites. These rings may be about fifty miles thick, but are thousands of miles across.

Saturn has nine or perhaps ten moons besides the tiny ones which compose the rings. One of these, Titan, is at least as large as Mercury. All these satellites revolve round Saturn in the usual direction, from west to east, except Phœbe, the most distant of Saturn's moons, which revolves from east to west.

190. *Uranus. Uranus was discovered in 1781 by a German musician, William Herschel, with the aid of a telescope which he made himself. This planet is probably similar to Jupiter and Saturn, but it is so far away that accurate observations of its features are difficult. It is known to have four moons, which revolve round it in orbits almost perpendicular to the plane of its own orbit.

191. Neptune. The story of the discovery of Neptune is one of the most interesting in the whole history of science. After Uranus was discovered the astronomers observed it to compute its orbit. To their surprise they did not find Uranus exactly where they had computed that it should be. Evidently it must be responding to the gravitational attraction of some other body besides the sun. No heavenly body was then known which could be producing this effect upon Uranus. A young Englishman named Adams and a young Frenchman named Leverrier independently began the attempt to solve the problem of Uranus's variation[1] from its computed path. In 1846 first Adams and then Leverrier arrived at practically the same conclusion, though neither knew of the other's work. They concluded that there must be another planet farther out from the sun which must be in a certain position in the sky to attract Uranus. When a search of that portion of the sky was later made with telescopes, Neptune was found in almost the exact place where Adams and Leverrier had predicted it would be. Thus the attraction was traced to its source.

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[1] *Variation* (va ri a′shun): the act of varying or differing.

*Neptune is Uranus's twin and is more like Uranus than Venus is like the earth. It is about thirty-six thousand miles in diameter. It requires one hundred sixty-four and a half years to revolve in its orbit round the sun, and it probably rotates in less than twenty hours. Little is yet known about its surface features, because it is too far away for even the great telescopes to reveal its surface clearly.

Group Report. Make a table of facts about the planets. Several of you had better work together in collecting information for the table. At least two should search for each fact in order to check up and be certain that the information is both correct and recent. Some of the data asked for in the table will be found in this book, but you will have to search in books on astronomy and in other reference books for the others. The data for the earth are given in the table. Can you, working together, fill in the rest?

FACTS ABOUT THE PLANETS

PLANET	DIAMETER IN MILES	DISTANCE FROM THE SUN	TIME OF ROTATION	TIME OF REVOLUTION	NUMBER OF SATELLITES
Mercury					
Venus					
Earth	8000	93,000,000	24 hours	365¼ days	1
Mars					
Asteroids					
Jupiter					
Saturn					
Uranus					
Neptune					

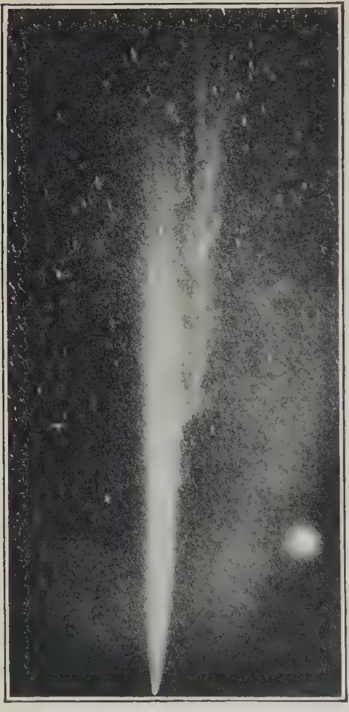

FIG. 167. HALLEY'S COMET, PHOTOGRAPHED MAY 13, 1910

The telescope was kept pointed at the comet; hence the stars made streaks on the photograph as the earth rotated. The bright spot at the right is Venus. The trail of a meteor crosses the comet's tail. (Photograph by E. C. Slipher, Lowell Observatory)

192. *Comets. Now and then astronomers in searching the heavens with their telescopes may note a dim little patch of light which they have not previously noted. Night after night they watch it. When they observe that it moves through the constellations, like the planets, they know that it is a comet. As it approaches nearer the sun it greatly increases its speed, for the same reason that Mercury travels more rapidly than Neptune. As it approaches the sun, moreover, the comet develops a tail which streams across the heavens for millions of miles (Fig. 167).

Up to the present time perhaps a thousand comets have been registered, but only a few of these have been visible without the telescope. Whenever they have been visible without a telescope, however, they have been regarded with awe and superstition. Even so recently as 1910, when Halley's comet returned (as it does every seventy-six years), there were ignorant and superstitious people who believed that the unusual spectacle of a comet in the sky was a bad omen, and who predicted all sorts of dire calamities, even the end of the world. But there is nothing unnatural about comets. They are controlled by the same natural laws and obey these laws in exactly the same way as the other members of the solar system.

193. *Meteors. If we watch the sky on a clear moonless night, especially in April, November, or August, we may see the streaks of light which are called shooting stars. They are not stars at all, but are small bits of matter which are pulled to our earth by gravitational attraction (see page 110). Falling at the rate of from twenty to thirty miles a second, they become incandescent chiefly by striking the air, just as a lead bullet sometimes becomes hot enough to melt when it is fired against a rock. They also gain heat by friction in passing through the air. Since they are incandescent, they are oxidized, or burned up (see page 42), before they reach the ground. Probably more than ten million of these meteors, weighing on an average less than an ounce each, burn up in the earth's atmosphere every day, leaving dust which slowly settles.

Meteors are now generally thought to be parts of comets and their tails, which have been broken up and scattered as innumerable fragments along the orbits of those comets. In fact, the breaking up of Biela's comet was observed by astronomers. This comet completed the circle of its orbit in a little more than six and a half years, and had been observed early in the last century. When it appeared in 1846 its head was seen to be in two parts; in a later trip the two portions were seen to be far apart. The comet was never seen again; but in 1872, when the earth crossed the trail of the vanished comet, there was a wonderful shower of meteors for several hours. Some of these meteors were "fire balls" that looked to be as big as the moon.

These phenomena, together with other less striking facts learned from other comets, convinced astronomers that meteors are portions of former comets.

194. Meteorites. Occasionally stones fall through our atmosphere to the ground. These are called meteorites; they usually weigh from a few pounds to several tons (see Fig. 168). There are many of these meteorites on exhibition in various parts of the world. The "Willamette," the largest known meteorite, is now on exhibition, together with many other meteorites, in the entrance arch of the American Museum of Natural History, New York City. It weighs about thirty-seven tons. No less than a hundred meteorites fall to the earth each year. Most of them are irregular lumps of stone, but a few are almost pure iron. Some small but genuine diamonds were once found embedded[1] in an iron meteorite which fell in Arizona.

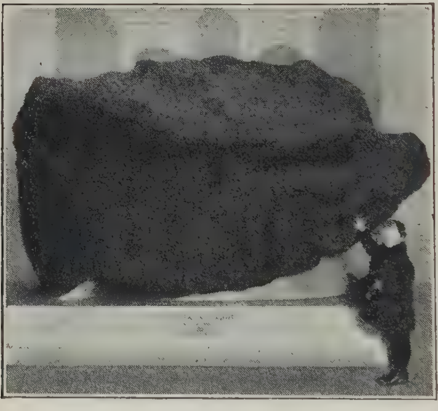

FIG. 168. THE WILLAMETTE METEORITE

This is the largest and heaviest meteorite known. (Courtesy of the American Museum of Natural History, New York)

195. †How our solar system was formed. Nobody knows for certain how the solar system was formed. The astronomers and other scientists have advanced several hypotheses[1] which attempt to account for the heavenly bodies. The one that is now most widely accepted by scientists is the planetesimal[2] hypothesis: If two suns happened to approach within perhaps a hundred million miles of each other, the gravitational attraction of each upon the other would produce enormous tides (see page 272). Finally the tidal force and the explosive force from within the sun would become so great that one or both of the two suns would expel some of their matter into the space round them. The result would be a nebula (Fig. 169, p. 290). In the middle would be a big knot of matter composed of most of the original sun. Scattered here and there through the cloud of dust and particles composing the nebula would be other smaller knots of various sizes. These would circle round the central knot in elliptical orbits. As they traveled in their orbits during succeeding ages they would gather up by gravitational attraction the smaller particles which came near them, just as the earth is now constantly gathering up meteors and meteorites. The larger knots after ages of time would grow into planets, and smaller bodies which were close enough to them to obey their gravitational attractions would circle round them as satellites. Other small knots, not near enough to the larger knots to become their satellites, would grow into independent small balls circling round the central sun knot as the asteroids and planetesimals do.

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[1] *Embed* or *imbed* (em bed′ or im bed′): to bury within a mass.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the statements on the following page. Numbers 2 and 4 are a new type of test.

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[1] *Hypothesis* (hy poth'e sis): a scientific explanation proposed but not fully proved. Plural, *hypotheses* (hy poth'e sēez).

[2] *Planetesimal* (plan et es'i ml): a small piece of matter in the heavens.

1. The planets and other bodies in the solar system are held in their orbits by **gravitational attraction energy weight inertia friction** ----.
2. In the following list of bodies find the one that does not belong with the rest: **comets meteors satellites asteroids sun meteorites nebula planets.**
3. The sun is about ---- miles in diameter. It is about ---- million miles from the earth.
4. In the following list of words find the three which do not belong with the rest: **moon Venus Saturn earth Jupiter Mars comets orbits Mercury Uranus Neptune Saturn.**
5. The smallest planet is ----; the largest is ----.
6. The four terrestrial planets in the order of their distances from the sun are ----, ----, ----, ----.
7. The four great planets in the order of their distances from the sun are ----, ----; ----; ----.
8. The moon's surface is **all very rugged all very smooth thickly covered with plant life very rugged in some portions and very smooth in others dotted with many lakes and other bodies of water.**
9. Eclipses of the sun or the moon sometimes occur at the first and third quarters.
10. It is known that on the surface of Mars there are **people like ourselves vegetation intelligent people who are somewhat like us intelligent beings who may not look like us in any way animals.**

SCIENTIFIC PUZZLES AND GAMES

Which of the five statements that follow each of the problems given here would a carefully trained scientist choose as best? Justify your answer by stating one or more of the scientific attitudes (see pages 8–10).

Problem 1. A teacher of general science asked this question in an examination: "Give two reasons why you believe the earth is round." One pupil wrote: "I believe the earth is round because you told us it is, and because the book says so, too."

a. The pupil's reasons were poor, because he had not found out the reasons why the teacher and the book said the earth is round.

b. His reasons were good, because teachers of science seldom make mistakes and books never do.

c. His reasons were poor, because he should have tried to find out for himself by experimenting whether the earth is round.

d. His reasons were poor, because both the teacher and the book might have made a mistake.

e. His reasons were good, because teachers of science and books on science are usually correct.

Problem 2. In many places, especially about Naples in Italy, many of the people believe that certain persons become cursed with the "evil eye," so that anyone whom they look at will fall sick or have other bad luck unless something special is done to break the charm.

a. The belief is silly.

b. In the cases of some people the belief is probably well founded.

c. There is very little doubt that the belief is sound.

d. It is hardly likely that there could be any sound foundation for such a belief.

e. I do not believe in the "evil eye," but I wouldn't risk having anything to do with anybody who was said to be cursed with it.

UNIT VIII. KNOWING THE EARTH

CHAPTER XVIII

THE CHANGING SURFACE OF THE EARTH

Some Questions this Chapter Answers

How old is the earth? How do scientists believe that the earth was formed? How does gradation change the earth's surface? What are the mechanical and chemical agents of weathering? What are the agents of erosion? What effects are produced by volcanism? What effects are produced by diastrophism? What is the relation between gradation and diastrophism? How are rocks classified? How are crystals formed? What are fossils, and why are they important? How do weathering and erosion affect the soil?

196. How old is the earth? It is not known for certain exactly how the earth was formed, and nobody knows exactly what were the various stages in its development to its present state and appearance. The scientists are constantly observing the heavens, the rocks, and the oceans in their attempts to learn the age of the earth and the ways in which it seems to have developed.

By piecing together the facts learned from their observations the scientists are slowly making their knowledge more thorough. They know, for example, that the earth is very old. It is probably not less than a hundred million years old and perhaps more than a billion. They also know that it is constantly changing in various ways. They know that these changes, following each other in an orderly way, are the results of natural causes or laws. They do not yet know the exact nature of all these laws.

197. *How the earth was formed. Not long ago scientists spoke of the outer portion of the solid earth as the earth's "crust." They believed according to ideas then held that formerly the earth was hot enough to be in a liquid, or melted, state. They thought that as it grew cooler a crust of solid rock slowly hardened over the melted interior. When the planetesimal hypothesis was proposed, however, the scientists who accepted it had to throw aside the idea that the earth was ever a melted, or molten, ball; they also had to throw aside the idea of an earth's crust as a solid layer over a molten interior.

*According to the planetesimal hypothesis the earth began millions and millions of years ago as a knot, or lump, of matter in a spiral nebula (Fig. 169). It was then much smaller than it is now. As meteors, meteorites (see page 284), and dust fell upon it, it slowly grew in size. In this early growing stage its surface is thought to have been a loose and porous mass. The separate pieces and particles of rock and compounds of metals lay scattered about, just as they fell as meteors, meteorites, and dust. At first the earth may not have been large enough to hold an atmosphere, or perhaps it was large enough to hold a thin atmosphere like that of Mars (see page 275). But as it slowly grew in size from age to age its gravitational attraction increased. It became gradually able to hold a denser atmosphere which included some water vapor.

The moon has no atmosphere. Why?

*Finally some of this water vapor condensed as rain. Some of the rain sank into the ground, some evaporated, and the rest flowed into hollows and formed pools. These pools were the beginnings of the oceans.

198. Changes on the earth's surface. As the mass of the earth increased, different processes began to make changes in its surface. When the earth had grown large enough to have an atmosphere the higher parts of the surface began to wear away or be graded down, this being known as *gradation*. Gradation is not the first of these processes which change the earth's surface, but the whole matter will be easier to understand if gradation is discussed first.

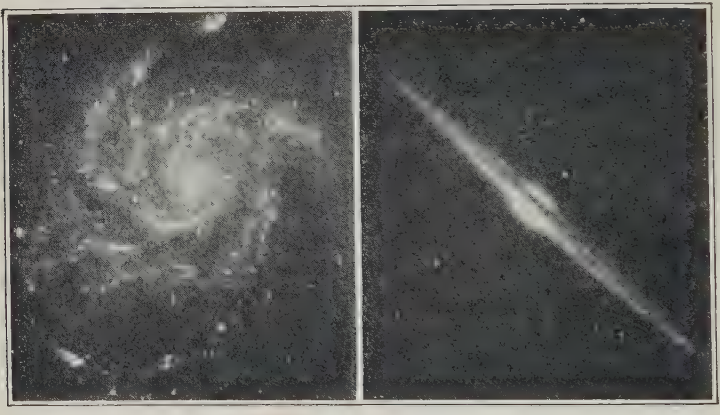

FIG. 169. TWO SPIRAL NEBULÆ

Note the "pinwheel" form of the first. The second has its edge toward us. If it could be seen from the front it would doubtless look much like the first. (Courtesy of Mt. Wilson Observatory)

*The process of gradation has to do with the transporting of materials from one part of the earth to another by wind, running water, and moving ice. Through the process of gradation soluble[1] materials and sediment are transferred by running water from the highest land to the oceans, and less soluble materials and heavy solid bodies are left behind. Likewise small solid particles are distributed over the earth by the winds, much of it falling in the ocean. Thus gradation cuts down the hills and builds up the valleys. In the course of ages the process of gradation has produced vast changes in the earth's surface.

*Gradation is the result of two processes, weathering and erosion. If it were not for the process of weathering, the surface of the land would be mostly unchanging bare rock. *Weathering* is the process of breaking up and changing the rock into soil. *Erosion* scrapes, scours off, and carries away other portions of the rock at and near the earth's surface.

*The agents of weathering are usually divided into two classes: mechanical agents and chemical agents. The common mechanical agents are freezing water, sudden changes of temperature, growing plants, gravity, and animals; chemical agents are substances in the air and substances given off by plants.

199. Mechanical agents of weathering. Weathering is produced by several mechanical agencies:

a. Freezing water changes the earth's surface. ***Experiment 36.*** Does water expand when it freezes? Fill a small thin-glass bottle or test tube with water. Insert the cork so that the bottle is exactly full when the cork is in. Tie the cork so that it cannot slip out. Immerse the bottle or tube in a pail containing cracked ice and coarse salt in the proportion of two or three handfuls of ice to one of salt. Leave the tube or bottle completely buried in this mixture for an hour or so. Then examine it. Answer with a complete sentence the question asked at the beginning of this experiment.

---

[1] *Soluble* (sol′u bl): able to be dissolved.

†Rain water is pulled by gravity into cracks and crevices[1] in the rocks. Later if this imprisoned water freezes, it expands with enormous force, splitting off flakes and sometimes huge pieces of rock.

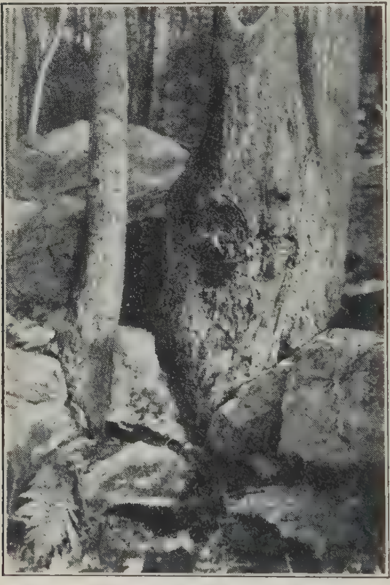

FIG. 170. TREES HELP TO MAKE SOIL BY BREAKING UP THE ROCK

b. Sudden changes of temperature affect the earth's surface. ***Experiment 37.*** Is glass broken up by sudden cooling? Heat a piece of glass tubing, then plunge it quickly into cold water. Answer with a complete sentence the question asked at the beginning of this experiment.

†The rapid heating and cooling of rock causes unequal expansion and contraction.[2] Sometimes rock which is heated by the sun and quickly cooled after the sun goes down is broken up in this way.

c. †Growing plants affect the earth's surface. Trees growing in crevices sometimes exert sufficient pressure with their roots to split off pieces of rock (Fig. 170). Even small and weak plants can accomplish this by giving off acids and other waste substances which chemically combine with the rock and weaken[1] its structure.

---

[1] *Crevice* (krev'is): a small crack or opening.

[2] *Contraction* (kon trak'shun): becoming smaller by drawing together.

d. †*Gravity affects the earth's surface.* The constant pull of gravity on rocks sometimes causes them to break and fall. In falling they may shatter other rock, making it possible or easier for other agents of weathering to act upon the rock.

e. †*Animals change the earth's surface.* Some animals, especially man, dig into the soil and rock, exposing them to the agents of weathering. Such animals must therefore be classed as agents of weathering.

200. †Chemical agents of weathering. *a. Changes are made by the chemical action of the air.* Carbon dioxide, oxygen, and other substances in the air combine chemically with substances in some rocks, causing the rocks to crumble.

b. †*Changes are made by the chemical action of plants.* Plants give off from their roots and from decaying leaves carbon dioxide and other substances. These attack the rocks and, by combining chemically with them, often weaken and crumble them.

Thus weathering slowly goes on, continually breaking up the rock into soil. If it were not for erosion, which removes the products of weathering, the weathering would finally stop because it would produce a sufficient covering of soil over the rock to protect the rock from further attack. Erosion carries off the weathered materials and exposes the rock for further weathering.

201. *Agents of erosion. *a. Ground water causes erosion.* Whenever it rains, some of the water sinks into the earth and becomes ground water. Ground water is never pure water. As it passes through the air it dissolves some carbon dioxide and oxygen. As it sinks through the ground it dissolves certain substances. If it becomes heated by coming in contact with volcanic rock, its solvent powers are increased. When the ground water containing all these substances in solution comes in contact with the rocks, it dissolves some of them and carries them away to the streams. Thus part of the dissolved minerals finally reach the ocean. The Mammoth Cave and similar limestone caves resulted from erosion of this sort.

---

[1] *Weaken* (weak′en): to make weak.

> *Special Reports.* Find out all you can about the wonders of the Mammoth Cave of Kentucky, the limestone caves of Virginia, New Mexico, Oregon, and those in other regions of the United States.

b. **Running water causes erosion.* When rain falls upon a land surface it is pulled by gravity toward lower levels, forming the streams and rivers. The steeper the slope, the faster gravity makes the water flow. As it flows over and through the loose weathered material it carries part of this material with it. Thus the water flowing in gutters and streams is yellow with mud particles following a rain. The heavier stones which a stream rolls along the bottom increase its friction, so that to the load of weathered material which it is already carrying, the stream adds other materials scraped and scoured from the stream bed.

> Why do rocks in the beds of mountain streams have rounded corners, while rocks of mountain slopes do not?

c. †*Winds cause erosion.* The friction of wind as it blows across the land causes the air to pick up and drag along bits of weathered material such as grains of dust and sand. When these solid particles are blown against rock, the rock is eroded[1] faster than the wind alone could do it (Fig. 171).

---

[1] *Erode* (e rode′): to remove by erosion.

d. **Waves, tides, and currents cause erosion.* The friction of the wind as it moves across the surface of the ocean produces waves which dash against the shores with enormous force. The tides and shore currents likewise constantly scrape and scour the shores. The surface waves, the tidal waves (see page 273), and the currents cut under the cliffs at the level of the water, gnawing out and carrying away the rock materials. When the cliffs have been sufficiently eroded at the bottom, gravity pulls down the upper portions. The cliffs thus slowly move back, and the land is worn away and is deposited bit by bit in the ocean.

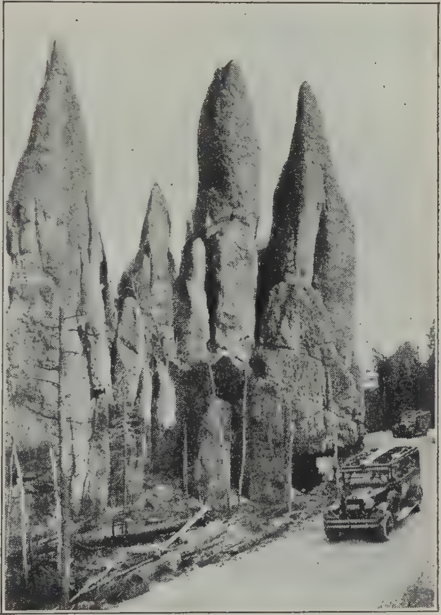

FIG. 171. WIND EROSION IN SOUTH DAKOTA

How many reasons can you think of to account for the fact that some parts of the rock are eroded more than others?

e. **Glaciers cause erosion.* When more snow falls in the polar regions and in the mountains in winter than melts during the summer, the snow slowly piles up in the upper valleys. Gravity packs it down, finally changing the snow into ice. Thus a glacier is formed (Fig. 83, p. 139). The glacier is slowly pulled down the valley by gravity, on the average only a few feet a day; but if the glacier is big enough to cover a whole region, it may take a year to flow only a few feet. The glacier digs its valley deeper and broader as it slowly moves down. It does not often reach the ocean, but deposits its eroded load when a point is reached where the melting at the end just keeps up with the downward flow of the glacier (Fig. 172). Some of the eroded rock is carried off at once by the streams formed by the melting glacier;

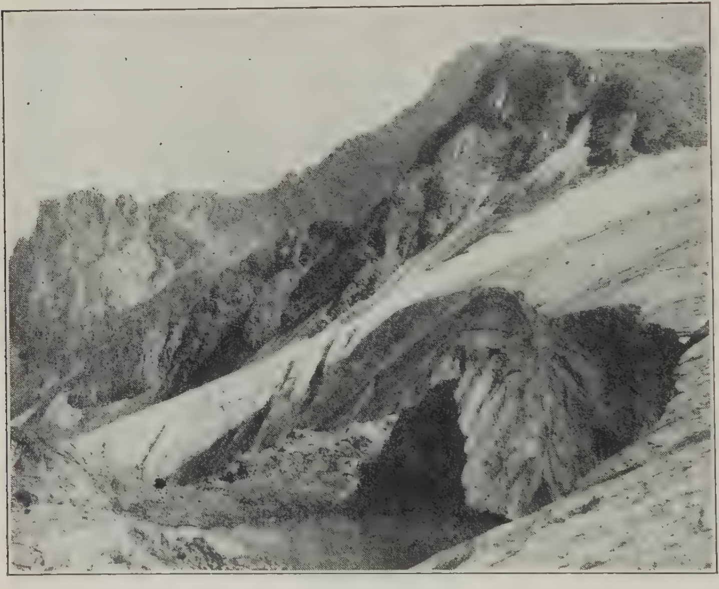

FIG. 172. GRASSHOPPER GLACIER, GLACIER NATIONAL PARK, MONTANA

What evidence of erosion by this glacier can you see? What causes the glacier to end at this point instead of higher up the mountain or farther down the mountain? What evidences are there to show that the end of the glacier is at this point? (Photograph by J. E. Haynes, St. Paul) the rest may remain for thousands of years where it was left by the melting ice, but bit by bit it is weathered down and finally carried by rills to the streams and by the streams to the ocean. The streams of Lower Canada and the upper United States are still transporting the material deposited by the great North American ice sheet, which tens of thousands of years ago covered most of Canada and the northern part of the United States.

202. *Volcanism. The process of volcanism has to do with the effects of heat within the earth. It affected the earth's surface before gradation did. To begin with, according to the planetesimal hypothesis the interior of the earth was not then as it now is. As its mass grew, its gravity increased. The pull of this increasing gravity on the matter of the earth caused more and more pressure. This pressure produced much heat (see page 152). Additional heat was caused by the breaking down of radium and other similar substances. Finally there was enough heat in the interior of the earth to melt some of the more easily melted materials. These molten materials formed small pockets here and there in the solid earth. These scattered pockets of molten matter were not many miles below the surface, because deeper in the earth the pressure was too great to allow materials to become liquid, no matter how hot they became.

The molten material slowly worked its way toward the surface. One reason why it did this may be that the tidal action of the moon and the sun (see page 272) attracts the molten material inside the earth in the same way that it piles up the tides in the ocean. Another reason may be that when the rocks, minerals, and metals are melted, they expand somewhat, thus they become less dense (see page 110) than when they are solid. Whenever shifts of material, such as may be caused by folding, occur inside the earth, there is a tendency for lighter materials to be crowded toward the outside because gravity pulls the heavier materials toward the center of the earth.

*Finally after long ages some of the molten material within the earth broke through to the outside in violent eruptions or in quiet flows of lava. These were the first volcanoes (Fig. 22, p. 49).

Through this process of volcanism layers of lava, or molten rock, were spread here and there over the earth's surface by volcanoes. But volcanism produced still other changes. Here and there great masses of volcanic rock were forced up through crevices, but cooled and hardened before they quite reached the surface. Also the volcanoes added gases to the atmosphere. Ages of gradation removed the materials above these hardened masses and exposed this volcanic rock.

203. Diastrophism. The process of *diastrophism* has to do with the warping and twisting of the surface as the materials of the earth are shifted under the pull of gravity. Three conditions have a tendency to cause diastrophism: (1) the uneven distribution of falling planetesimal material, (2) the shifting of materials by volcanism, and (3) the shifting of materials by gradation. These three conditions throw the earth out of balance. Gravity restores this balance by elevating and depressing[1] portions of the earth. During this rising and sinking there is always the tendency for the heavier materials to move nearer the center of the earth and crowd the lighter materials upward. It is known that materials under the oceans are somewhat heavier than those of the land areas. Hence diastrophism raises the continents higher and deepens the oceans.

---

[1] *Depress* (de pres'): to cause to sink down.

*When continents are squeezed by diastrophism the borders become crumpled[1] up most, so that mountain ranges are produced. During this process the rocks are so strained that rock masses sometimes break and slide over one another, causing earthquakes. Also the moving and breaking up of rock masses gives molten materials below the best chance to reach the surface. Hence volcanoes as well as earthquakes frequently occur in mountain ranges along the edges of continents.

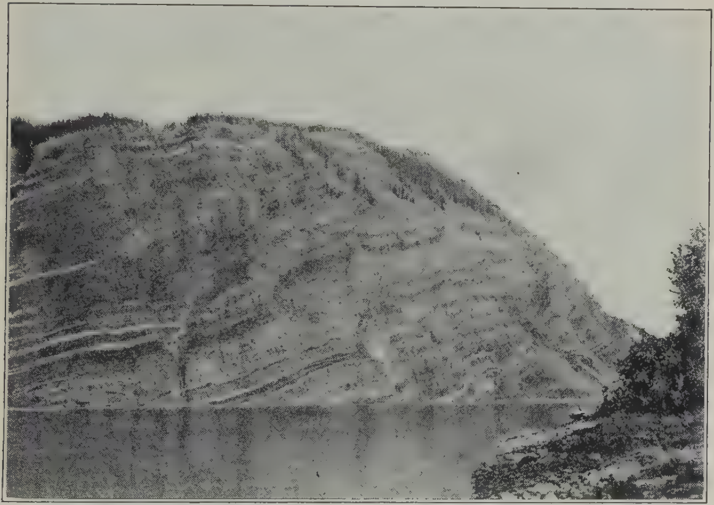

FIG. 173. CALICO BLUFFS ON THE YUKON RIVER, ALASKA

What evidences of diastrophism can you see in this picture? What evidences do you see that these rocks were once under water? (Courtesy of the United States Geological Survey)

Sometimes the wrinkling of the earth's surface tilts up and forces above the oceans great layers of sedimentary[2] rock (Fig. 173). It is known, for example, from the remains of plants and animals embedded in the rock that parts of the state of New York have been elevated above the ocean and later depressed beneath it at three different times, probably millions of years apart.

---

[1] *Crumple:* to squeeze together, forming wrinkles.

[2] *Sedimentary* (sed i men′ta ry): formed of sediment.

*The preceding paragraphs may be summarized thus: The surface of the earth has been undergoing constant gradual changes from its very beginnings. First its outer covering slowly deepened from age to age as the planetesimals fell. The more striking changes came later, however, (1) after the earth developed heat enough to produce *volcanism*; (2) after it had grown sufficiently to hold an atmosphere which made possible *gradation* by wind, ice, and running water; and (3) after its increasing gravity caused *diastrophism*, which wrinkled the land into mountains and lifted the sheets of sedimentary rock above the water.

*When after millions of years living things appeared on the earth, these also produced changes in the earth's surface in addition to all those which had been produced and were still being produced by the older causes.

204. Gradation and diastrophism produce opposite effects. The final result of gradation by weathering and erosion (Fig. 174) accomplished by all the various agents is gradually to make the earth's surface level by carrying the land down into the ocean. It is estimated that the Mississippi River alone deposits in the Gulf of Mexico on an average more than forty thousand tons of sediment every hour. It is estimated also that all the rivers in North America are lowering the average level of the continent at the rate of about an inch every seven hundred fifty years.

If gradation were to continue long enough without interruption, all the land now above the water would be carried into the ocean. There is interruption, however, in the form of diastrophism. Diastrophism warps and crumples the ocean bottom as well as the land, elevating areas here and depressing other areas elsewhere.

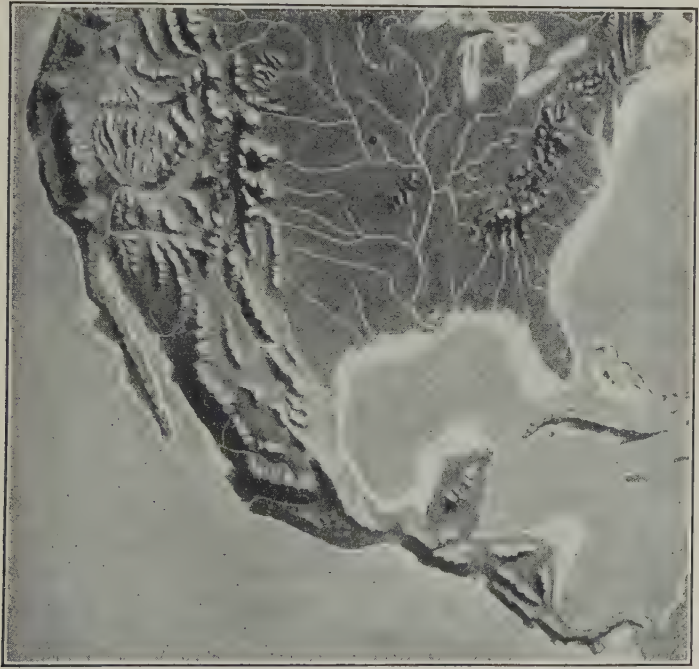

FIG. 174. LAND LEVELS AND SEA-BOTTOM LEVELS SHOWING DIASTROPHISM AND GRADATION

What evidences of gradation and diastrophism can you see in this picture?

For a long period of time gradation may go on changing the earth's surface faster than diastrophism, then diastrophism may produce the greater changes. For example, about one fourth of the earth's surface is now above water.

But ages ago there were times, after the process of gradation had been going on for thousands of years without interruption, when only about one eighth or even one twelfth as much of the earth's surface was above the oceans. Just at present diastrophism is producing greater changes than gradation, with the result that the land areas are growing faster than they are being worn down. But from age to age diastrophism and gradation balance each other well enough so that about the same area of land remains above water.

205. The classification of rocks. Rocks differ from each other in various ways. The particles of which they are composed are of different kinds, sizes, and shapes. Some are in layers; others are not; some have their particles weakly cemented together, and others have them very firmly cemented. These differences are largely due to the way in which the different rocks happened to be formed.

*Rocks are usually grouped into three classes: (1) the *sedimentary* rocks, (2) the *igneous* (fire) rocks, and (3) the *metamorphic* (changed) rocks. *Sedimentary rocks* are formed by the cementing together of deposits of sediment. Thus, gravel deposits are cemented together to form conglomerate; clay, to form shale; sand, to form sandstone; and the shells and remains of ocean animals, to form limestone. Coal may be considered to be a sedimentary rock made of the remains of ancient plants.

206. †Crystals. Sometimes water contains dissolved minerals in great quantities, as in the water from mineral springs. When this water evaporates or is cooled, the minerals deposit in the form of crystals. Rock salt is a familiar example of such crystals. Crystals are also formed when certain kinds of molten rock are cooled.

Experiment 38. Make solutions of salt, copper sulphate, and potassium permanganate by dissolving them in hot water. Place a narrow strip of wood over the top of each glass containing one of the solutions. Hang some pieces of thread over the strips of wood so that the ends extend into the solutions. Put the three glasses aside where the water will slowly evaporate. Crystals will form. Are they alike in shape?

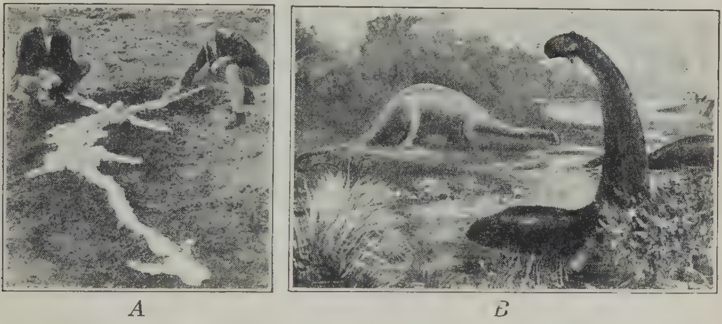

FIG. 175. DIGGING OUT A FOSSIL, AND ANIMALS OF THE PAST

A: This creature was a fish-like reptile. These reptiles lived on the earth thousands of years before there were any men. Some were larger than any animals now living, while others were as small as our present small lizards. By studying the fossil remains, scientists are able to determine how these reptiles looked and how they lived. By studying the rock layers in which and below which the fossil is found, the scientists are able to tell how long ago the reptile lived. *B:* These are huge dinosaurs, or great reptiles, which lived on the earth long before there were any men. This picture was painted after a careful study of the facts which scientists learned from studying the fossil remains of these reptiles. (*B*, by courtesy of the American Museum of Natural History)

207. †Fossils. The bones and shells of animals which lived on the earth ages ago are frequently found in great numbers in sedimentary sandstone and limestone (Fig. 175, *A*). The flesh and softer parts of these animals decayed before their bodies became covered with sediment, but before the bones and shells could decay they became covered and were preserved. Later the sediment was changed to rock. Such remains are called *fossils*. But not all the fossils are the bones and shells of ancient animals found in rock and in soil deposits; sometimes the fossil consists of the footprint of an animal, or the impression of a plant in mud which later changed to shale, or the burrows of worms in ancient sea sand which later changed to sandstone.

†Fossils are important for several reasons: they show in what places land, lakes, rivers, and seas existed in ancient times, they tell of changes in climate which occurred ages ago, they give knowledge concerning the distribution of ancient animals of various kinds (Fig. 175, *B*), and they furnish a record of the past which enables scientists to determine much of the early history of the earth since animals and plants have lived on it.

> *Special Reports.* Find out what petrified wood is and how it is formed. Describe the Painted Desert in Arizona. How was it formed?

208. †Igneous rocks the result of volcanism. Many kinds of rocks were formed when the substances composing them were melted by the heat of the earth's interior and later cooled. Pumice, obsidian, and granite are familiar examples. Many of these "fire rocks" take a crystalline[1] form as they cool; granite, which cools slowly under great pressure, is formed of fine crystals.

Metamorphic rocks are formed from both igneous and sedimentary rocks by very high temperatures, pressure, water inside the rock, and sometimes movement of the rocks which causes them to lose their former structure and to form new and different rocks. Marble is sedimentary limestone changed by heat to crystalline rock; slate is shale or sometimes mud changed by pressure but not necessarily with great heat.

---

[1] *Crystalline* (kris′tal in): formed of crystals.

209. *How do weathering and erosion affect the soil? We have just learned that soil is formed from the solid rock, or bed rock, by the action of *weathering* and *erosion*. Soil that remains above the bed rock from which it was formed is called *residual*[1] *soil.* Residual soil is always weathered soil. Soil that has been carried from the place where it was formed and deposited somewhere else is called *transported soil.* Transported soil is eroded soil.

> Why is residual soil always weathered soil? Why is transported soil always eroded soil?

*We have learned that the bed rock undergoes chemical changes during the process of weathering; hence residual soil is different in substance from the bed rock from which it was formed, but it is uniform at any given place. Residual soils differ greatly from one another also, because the bed rock from which they are formed differs greatly.

*Transported soil is usually very different from the rock upon which it rests, because it consists not only of weathered soil from a wide variety of places but also of portions scoured and scraped from all the rocks over which the agents of erosion passed while transporting the soil.

It is estimated that on the average the agents of weathering produce a foot of residual soil in the United States every ten thousand years. This seems very slow; yet weathering produces residual soil faster, on the average, than it is transported away by the agents of erosion. We should expect, therefore, to find fine soil above the bed rock generally except on the steeper slopes. But man upsets the usual course of nature. By cutting away the forests and by plowing the land for his crops he exposes the soil to erosion. The result is that the soil is eroded away so much faster than it is formed by weathering that over large areas all the fine fertile soil is gone, and the remaining land is good for nothing (Fig. 176). Wherever this soil is deposited by rivers there are usually fertile tracts; in fact, the great civilizations three thousand years ago were confined almost entirely to the flood plains of rivers.

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[1] *Residual* (re zid′u al): remaining in its original place or the place where it was formed.

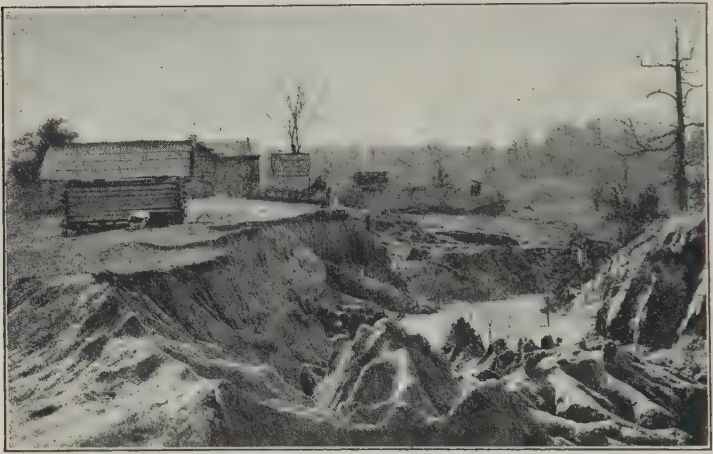

FIG. 176. DESTRUCTION OF A MISSISSIPPI FARM BY EROSION

How could this destruction of fertile land have been prevented? Can anything now be done to save what good soil remains? (Photograph by W. R. Mattoon, United States Forest Service)

*As the population of the earth continues to increase, however, there is more and more need to conserve the fertile soil. Farmers have learned several ways in which erosion may be decreased: (1) that erosion is less rapid when they plow across the slopes instead of up and down; (2) that they can decrease erosion by the method shown in Fig. 177; (3) that the more deeply and the more frequently they till the soil, the slower the erosion will be because the soil will absorb more rain, thus reducing the amount which runs rapidly away over the surface; (4) that soil erodes more slowly if it is covered with crops, grass, or forests. How many reasons can you give why this is true?

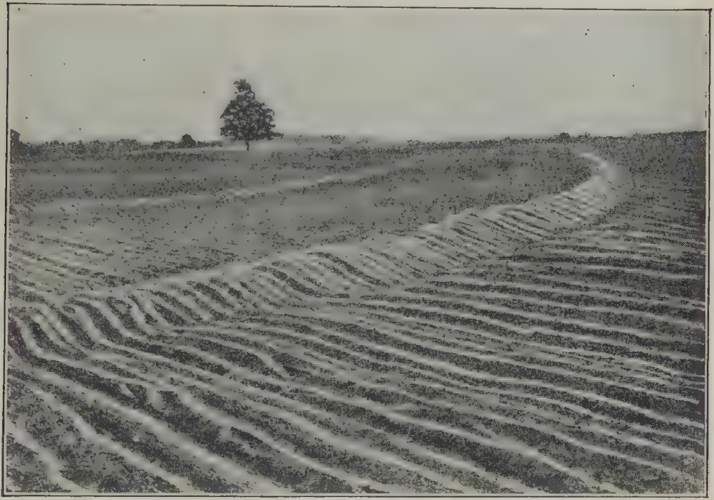

FIG. 177. ONE WAY TO PREVENT EROSION

How do the terraces, or raised "steps" or furrows, prevent the running water from eroding the soil on this North Carolina farm? (Courtesy of the United States Department of Agriculture)

Experiment 39. Does a stream furnish evidence of gradation and erosion? Fill a glass with the yellow water of a stream after a rain. Put it aside for several days where it will not be disturbed. Does the color of the water change? Can you account for the phenomena you observe?

Experiment 40. Does water sort soil? Put into a fruit jar several handfuls of dirt containing fine and coarse particles, including sand and gravel. When the jar is half full, fill it the rest of the way with water. Put on the cover, then shake the jar back and forth vigorously until the water is all through the soil. Quickly place the jar upright and do not disturb it for a day or so. Explain your answer to the question asked at the beginning of this experiment.

Experiment 41. What can a magnifying glass show us about soil? With a magnifying glass examine a handful of soil. How many different kinds of particles do you see? Do you find any animal or vegetable matter? Examine sand grains to see whether the corners are sharp or rounded. Can you tell from their sharpness or roundness whether they are residual or transported?

*Other differences in transported soil are due to the nature and actions of the various agents of transportation (erosion). Wind and running water are to some extent able to sort the soil. Thus light winds can pick up dust and finer particles, and heavier winds can transport sand. Slow-moving streams can carry fine particles only; swift streams can transport gravel and even rocks. When running water has its speed reduced by running from a hillside on to level ground, it drops its load in a mixture of fine and coarser pieces. When running water flows into the still water of a lake or ocean, the heavier particles are dropped nearest the shore and the finer particles are carried farther out. The soil at the end of glaciers is unsorted. It consists of weathered soil scraped from the valley sides and of unweathered soil scoured from the surfaces of the rocks over which the glacier passed.

*The result of all these different factors is that we sometimes find uniform beds of soil, such as sand, clay, or gravel, near other uniform beds which are entirely different; or we may find all sorts of mixtures of the various kinds of soil.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. Astronomers believe that the earth was formerly much larger than it now is.
2. The age of the earth is known to be **many years many hundreds of years many thousands of years many millions of years many billions of years.**
3. The hills are gradually leveled and the valleys gradually filled by the process of **weathering volcanism diastrophism gradation irrigation.**
4. The center of the earth is composed of very hot matter which is **liquid solid half liquid, like warm tar gaseous almost a vacuum.**
5. Mountain ranges are produced by the process of **erosion weathering gradation diastrophism volcanism.**
6. All volcanic rocks are called **metamorphic igneous sedimentary fossil crystal.**
7. If the earth had never had an atmosphere, there would now be little soil on the surface.
8. Forests and trees prevent too rapid weathering of the soil.

CHAPTER XIX

THE EARTH AS A STOREHOUSE

Some Questions this Chapter Answers

In what sense is the earth a storehouse? What are geysers, and how are they caused? How was coal formed? What is petroleum? Why is it important? How are some valuable substances produced from petroleum? Where is natural gas found? How do minerals differ from rocks? What are some important metallic minerals? Why are they important? What are the kinds and characteristics of the common building stones? What is glass, and how is it made?

210. Stores of energy and raw materials. From earliest times the earth has been a storehouse[1] from which man has secured the various substances to satisfy his needs. When his needs were simple he drew upon this storehouse for only a few raw materials, such as stone for his weapons. As he slowly added to his knowledge of science he learned how to use more and more of the raw materials on and in the earth. He learned, for example, how to mine a few metals and to make them into implements. These metal implements, which were better than the earlier stone ones, enabled him to improve his manner of living in many ways and to secure still other materials from the earth. Thus it may be said that man's progress toward civilization depended upon his progress in science.

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[1] *Storehouse* (stor′house): a place in which supplies are stored and from which supplies are drawn.

*Science has taught us how to use two kinds of substances from the storehouse of the earth: (1) those which furnish energy (see page 119) and (2) those which serve as raw materials to be made up into various articles we need. Although scientists have already discovered many different kinds and sources of energy, it is very unlikely that they have yet discovered all that the earth has in store for us. Also it is certain that they will continue to learn how to make new and valuable things out of raw materials which are now considered worthless, just as they have recently learned to make many useful articles out of cornstalks and corncobs.

*Among the sources of energy which the earth provides and which man has already learned to use are these:

1. The mechanical energy of moving air, which is used to drive boats, to turn windmills, and to carry balloons.
2. The mechanical energy of running water, which is used to turn the wheels of mills and to generate electricity (see frontispiece).
3. The chemical energy of various kinds of foods.
4. The mechanical energy of sound waves, which are used for communication and music.
5. The chemical energy of various fuels.
6. The energy of light, which serves us in so many ways.

*Among other sources of energy that may be found on the earth, but that man has not yet learned to use on a large scale, are the mechanical energy of the tides, the direct heat energy of the sun, and the heat energy in the interior of the earth.

211. Volcanic energy: geysers. In many portions of the country there are hot springs. The water of these springs is heated by hot rocks just below the earth's surface. Visitors to Yellowstone Park see not only hot springs but wonderful geysers. These are natural fountains which every little while spout boiling water and steam many feet into the air. Old Faithful is the most famous of these.

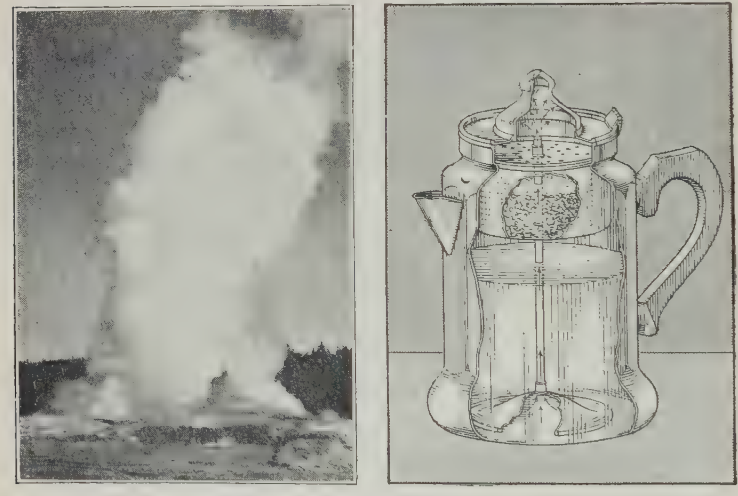

FIG. 178. THE CASTLE GEYSER, YELLOWSTONE NATIONAL PARK, AND A COFFEE PERCOLATOR

The coffee percolator spouts for the same reason that a geyser spouts. After reading the explanation of the geyser, can you explain why the coffee percolator spouts hot water?

*These geysers spout for the same reason that hot water spouts up in a coffee percolator (Fig. 178). The pipe of the geyser from which the water spouts is a long, narrow, chimney-like opening in the rock. Water slowly flows or drips into this pipe, partly filling it. At the bottom are hot rocks. You will remember that water begins to boil when it becomes 212° F. provided the pressure on the water is the normal pressure of the atmosphere. The weight of the column of water in the geyser pipe makes the pressure on the water at the bottom greater than the normal pressure of the atmosphere; consequently the water does not begin to boil at 212° F. but remains liquid, though it continues to get hotter. Finally it becomes hot enough to boil, even though it is under great pressure in the pipe. As soon as some of the water at the bottom is changed to steam, it expands rapidly and pushes some of the water out at the top. Immediately the pressure on the water at the bottom becomes less because there is not so much water above it. At once the water at the bottom of the pipe begins to boil more violently because the pressure on it is decreased. Steam is therefore generated so rapidly at the bottom that the remaining water in the pipe is forced out with great violence, sometimes to a height of two hundred feet. It is possible that before many years engineers will invent ways of using the energy of hot springs and geysers for steam power.

Which geyser should you expect to spout most often, one with a short pipe or one with a long pipe, provided the conditions otherwise were just alike? Why? Which should you expect to spout higher? Why? Can you think of two reasons why the ground around the openings of geysers is coated with deposits of mineral matter (see page 59)?

212. *Coal. Ages ago the coal that we now burn grew as trees and other vegetation in swampy land at the mouths of rivers. The swamp in which this vegetation grew was lowered by diastrophism (see page 298). The river then, by erosion (see page 294), brought down sand and clay and covered the vegetation with these. Later the covering bed of sand and clay was raised enough by diastrophism to let vegetation grow upon it. This growth in turn was lowered by diastrophism and covered by sand and gravel brought by erosion. In this way often several layers, or strata, of vegetable matter were buried under strata of sediment. The vegetable matter was probably partly changed to coal by the action of bacteria, and the heat and pressure due to the weight of the sedimentary strata over it completed the change. Layers of coal two hundred feet thick have been found in France and India.

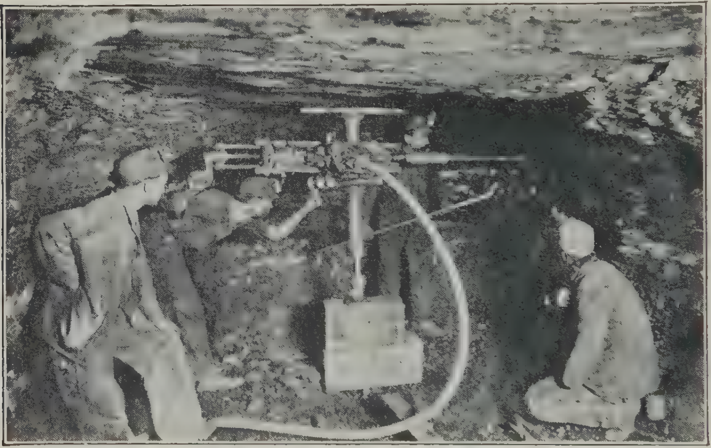

FIG. 179. MODERN COAL MINING

The compressed-air drill is making a hole in which to put explosives for a blast

*Coal is composed mostly of carbon. It also contains hydrogen, oxygen, and other substances, including ash.

Coal is found in every continent of the world, though Africa is thought to contain less than the other continents. Vast deposits are found in every country of North America. Coal is mined extensively in the great manufacturing regions of the East, in the Middle West, in portions of the South, and in the Rocky Mountain states (Fig. 179), but most of the Atlantic, Pacific, and Gulf states lack coal deposits. Most of the coal in this country is bituminous, or soft, coal. Practically all the anthracite, or hard, coal is mined in eastern Pennsylvania.

Special Reports. Discuss the yearly production and the various uses of coal in the United States. Describe the manufacture and the uses of coke. Locate on an outline map of the United States the most important coal deposits.

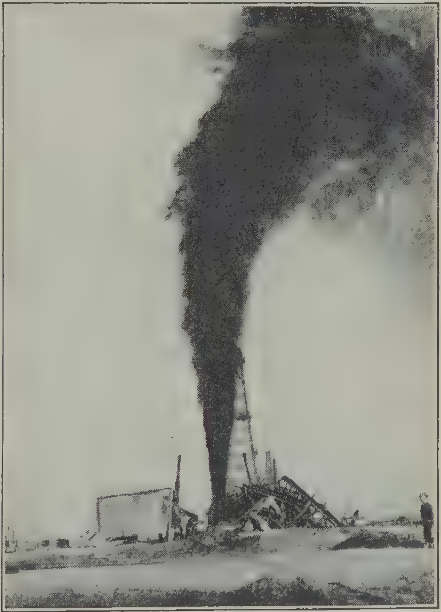

FIG. 180. AN OIL GUSHER AT LONG BEACH, CALIFORNIA

What causes the oil to spout from the top of the pipe?

213. *Petroleum.

Petroleum, or crude oil, is a thick liquid which may be pale yellow, red, brown, or black, though it usually looks greenish black. It is believed to have been formed by the slow decomposition[1] of ocean plants and animals buried ages ago under layers of sediment. It is found in porous rock

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[1] *Decompose* (de kom poze′): to break down a substance into simpler substances. *Decomposition* (de kom′po zish′un): the process of decomposing.

(usually coarse sandstone, conglomerate, or limestone), which it saturates in much the same way that water saturates a sponge. Sometimes these oil deposits are near the surface; sometimes they are at a depth of several thousand feet. A nonporous layer of rock, such as shale, above the oil-bearing rock, keeps the oil from escaping.

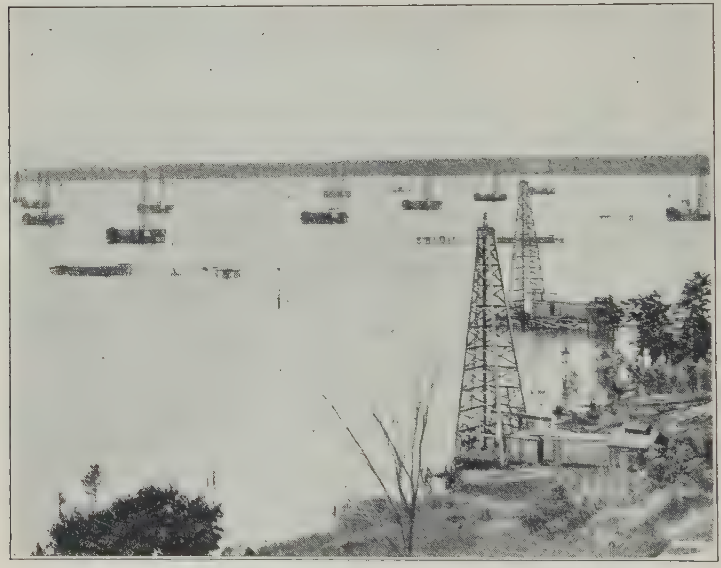

FIG. 181. AN OIL FIELD UNDER THE LAKE NEAR SHREVEPORT, LOUISIANA

Many similar wells are located under the ocean bed off the coast of southern California. (Photograph by Ewing Galloway)

A hole from six to eight inches in diameter is drilled through the nonporous rock into the oil-bearing rock. Sometimes when the oil is reached, it spouts out of the top of the pipe. Such wells are known as "gushers" (Fig. 180). The oil is probably forced from gushers by the pressure of natural gas above the oil acting upon the oil in much the same way as the compressed air in the tank of a compressed-air water system (see page 80). Sometimes the oil does not rise to the surface and has to be pumped.

Petroleum was used to some extent as far back as we have historic records. Early in the nineteenth century it was used in this country as a medicine; but the growth of the petroleum industry did not begin in the United States until August, 1829, when a well flowing twenty-five barrels a day was dug on Oil Creek, Pennsylvania. Extensive oil fields have since been discovered and developed (Fig. 181) in Ohio, Indiana, Illinois, Oklahoma, California, and many other states, and in Canada. It has been estimated that in every nine years since 1860 as much petroleum has been taken from the earth as in all the preceding years put together.

214. Gasoline. Gasoline is the most valuable product secured from petroleum. Petroleum in its natural, or crude, state is not very largely used. It has some use as a road covering to lay the dust and as a fuel. The products which chemists have learned to make from crude petroleum are of the greatest value.

*Chemists have learned that petroleum is a mixture of many valuable chemical compounds of carbon and hydrogen, called *hydrocarbons*. These different hydrocarbons are separated from the crude petroleum by distilling it in much the same way that water is distilled (see page 59). The most valuable of the hydrocarbons are gasoline, kerosene, benzine, naphtha, petroleum, ether, gas oils, lubricating oils, vaseline, and paraffin. Each of the hydrocarbons in the petroleum boils at a different temperature from all the others. When the petroleum is heated to the proper temperature to secure one of these hydrocarbons, therefore, this hydrocarbon boils off from the petroleum. Most of the other hydrocarbons, which boil at higher temperatures, are left behind as liquids. As the vapor of each hydrocarbon comes off from the heated petroleum it is condensed and purified. When the more valuable hydrocarbons named above are distilled out of the crude petroleum, what is left is sold for fuel oil, though it still contains asphalt, which can be obtained from it. Such fuel oil is used for heating our homes and office buildings and as fuel for merchant ships and even battleships.

†Some scientists have estimated that if we continue to use gasoline at the present rate, all the known supplies of crude oil will be exhausted within the next ten years. More gasoline is being consumed every year, because more people are using it as fuel in automobiles and in farm and other machinery. Unless new oil fields are discovered or unless chemists can invent some other process which will make it possible to get more gasoline out of petroleum, it seems certain that within a few years either there will be fewer automobiles in use or the automobiles will have to be so made as to burn some other fuel, such as alcohol.

215. †Natural gas. Natural gas is found in more than half the states of the Union. It usually is found in regions where petroleum occurs and is extracted along with the petroleum. Enormous quantities of it are being allowed to escape from the ground unused. It has been estimated that unless new supplies are discovered the known supplies will be exhausted within another twenty-five years.

216. *Minerals and rocks. The raw materials which man secures from the earth are mostly minerals and rocks. A mineral may be either a single element or a compound of two or more elements (see page 51). When it is composed of more than one element, the elements are always in the same proportions. Thus pure quartz is always a compound of oxygen and silicon in the same proportions. Consequently one sample of a mineral has the same properties as any other sample of the same mineral. The metals are all minerals.

*A rock is usually composed of two or more minerals not combined chemically but mixed. The proportions of the minerals composing the rock may vary considerably in the same kind of rock. Thus a sample of common granite contains the three minerals quartz, feldspar, and mica, but the particles of each of these minerals are easily seen to be separate in the granite. Furthermore, a piece of granite may contain only a little quartz in proportion to the amount of mica and feldspar, or it may be half quartz.

An ore is a rock or mineral containing one or more metals. The mineral ores are usually composed of a metal combined chemically with oxygen or sulphur.

217. ***Metallic**[1] **minerals.** *Iron* is the most valuable of all the metals. This statement does not mean that an ounce of iron is worth more than an ounce of any other metal. We know this is not true, for there are many metals besides gold and silver which are worth more by the ounce than iron. But iron is the most *useful* of all metals, and, next to aluminum, is most abundant.

How many uses of iron and steel can you name in five minutes?

Special Reports. Locate on an outline map of the United States the chief deposits of iron ore. Diagram a blast furnace and explain its action.

†*Steel* is made from cast iron. Steel is never pure iron, but contains from 1.6 per cent to 2 per cent of carbon. Part of this carbon is chemically combined with the iron

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[1] *Metallic* (me tal′ik): containing a metal, like a metal, or being a metal.

and part is merely mixed with it. Sometimes the steel is alloyed with other metals. An *alloy* is formed by melting two or more metals together. Thus various kinds of steels for different purposes, such as tools, automobile and airplane parts, safes, and machinery, are made by alloying the iron with small amounts of nickel, tungsten, chromium, and other metals, besides carbon.

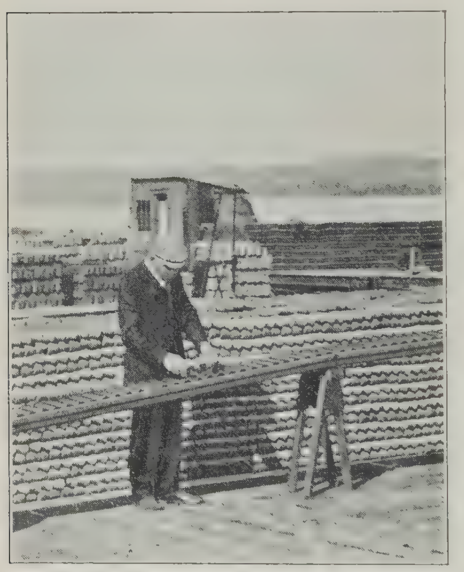

FIG. 182. PILES OF COPPER BARS AWAITING SHIPMENT AT CALUMET, MICHIGAN

†*Copper* is probably, next to iron, the most useful of all the metals. Long before the white men came to America the Indians had found copper along the southern shores of Lake Superior. They used it chiefly for arrowheads.

†Copper ores are found abundantly in many parts of the United States, principally in the West (Fig. 182). Copper is made into many useful articles, among them electrical wires, nails and sheets for ship bottoms, window screens, and roofing. Brass, an alloy of copper and zinc, and bronze, an alloy of copper and tin, are used in making ornaments and house fittings. Statues are often made of bronze.

How many other uses of copper can you add to those just given?

Copper kettles were formerly much used for cooking, and to some extent they are still so used. But vinegar and the juices of acid fruits (see page 116), such as berries and tomatoes, combine chemically with copper to form substances which are more or less poisonous; therefore iron and aluminum are better materials for cooking vessels than copper.

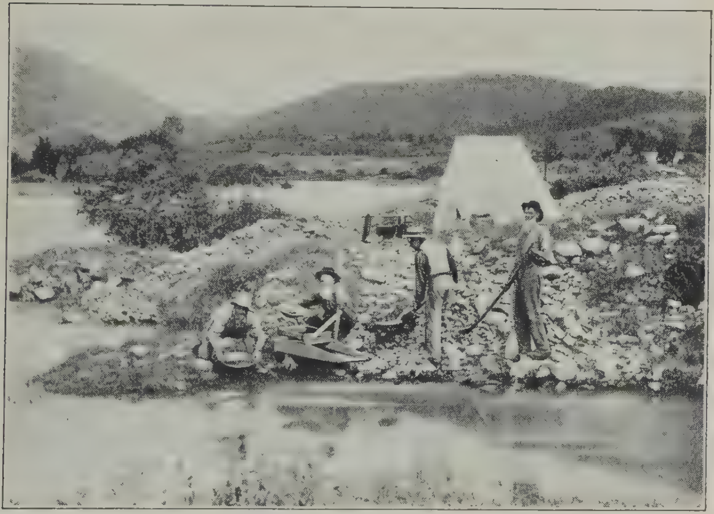

FIG. 183. WASHING GOLD FROM THE RIVER GRAVEL, AMERICAN RIVER, CALIFORNIA

This is near the spot where gold was first found in California in 1849. The gold was panned in this same way in the early days

> Why is copper a better metal than iron for window screens and for nails and sheets for the bottoms of ships?

**Gold* is the most beautiful of all the metals, but compared with iron and copper it is not very useful. Pure gold is always yellow. The white gold, green gold, and red gold used in jewelry are all alloys of gold. Pure gold is too soft to be used for coins and jewelry unless it is alloyed with copper or other metals.

Gold is found in our Western states, chiefly California, Colorado, and Nevada, and in Alaska. It is often found in the form of flakes or small lumps mixed with sand and gravel (Fig. 183). Pure gold is also frequently found in quartz veins. There are a few gold ores in which the gold is combined with other substances.

†*Mercury* is interesting because it is the only metal which is in a melted, or liquid, state at ordinary temperatures. In fact, it does not freeze (become solid) until the temperature becomes −39° C. Mercury is seldom found free in nature, like gold and copper, but is usually obtained from ore in which it is combined with sulphur.

Mercury is one of the densest metals. Iron, copper, zinc, tin, and lead will all float in mercury. Mercury is used in thermometers and barometers, in mercury-vapor lamps, and in some explosives. When alloyed with other metals it has a number of uses. The backs of cheap mirrors are "silvered" with an alloy of tin and mercury, and an alloy of silver, tin, and mercury is used for fillings in teeth. Various compounds of mercury are widely used in medicine.

**Radium* is the most unusual of all the metals. Both radium and its compounds are constantly giving off energy in the form of light, heat, X rays, and two other kinds of rays. Radium also breaks up of itself and forms two other entirely different elements.

*Much experimenting is being done with radium, but few uses have yet been found for it. Its compounds, however, can be used to make luminous paint. The rays from its compounds, moreover, kill bacteria, and hence radium is being widely used in medical experiments.

It takes about five hundred tons of radium ore to make one gram (see page 145) of radium. Because radium ore is not found in large quantities anywhere in the world, and because radium is so difficult to separate from its ores, it now costs about $70,000 per gram. At this rate a pound (if a pound could be obtained) would be worth at least $30,000,000.

†*Silver* is obtained from its ores, which are mined in several of the mountain states of the West. It is used chiefly for coins, jewelry, and table silver; it is also used in silvering expensive mirrors. Its salts (see page 116) are valuable in photography (see Chapter XXXIV). Silver, like gold, is too soft to be used for coins in its pure state, and hence it is alloyed with a small percentage of copper.

†*Aluminum* is the lightest of all the common metals. Pure aluminum is never found in nature, but it is a part of clay and many rocks. Aluminum is used for many purposes: as a paint for metal surfaces and in making electrical wires, parts of opera glasses and telescopes, metal parts for boats, airships, and automobiles.

> ***Special Report.*** How many other uses of aluminum can you find at home and elsewhere?

218. †Nonmetallic minerals. *Chalk* is limestone. The chalk cliffs of England are great beds of the shells of exceedingly small ocean animals that lived ages ago. Much of the chalk we use in the schoolroom is chemically the same substance as limestone, but is artificially made. Chalk makes an excellent tooth powder, because it contains no rough, hard particles.

†*Lime* is made by heating limestone. It is employed extensively in building, where it is used in whitewash, mortar, and plaster.

**Cement* is made of limestone and clay, heated and powdered. When it is mixed with water it hardens into rock. Concrete is made by mixing sand, cement, crushed stone, and water. Reënforced concrete is concrete made stronger by running rods of iron or steel through it when it is being poured.

Cement mortar is mixed with pebbles to make stucco, which is used in covering buildings.

How many uses of concrete and reënforced concrete can you think of?

Project. To make concrete and reënforced concrete and to see which is stronger. Stir together five parts of dry coarse sand and one part of dry cement. When they are thoroughly mixed add water, stirring meanwhile, until you have a thick paste. This is concrete. Secure two boxes of the same size. Fill one with the concrete. Put a layer of concrete in the other, then put a piece of wire screen on top of this layer. Add another layer of concrete and another piece of screen on top of this, and so on until the box is filled with several layers of concrete with wire screen between them. Keep the concrete in both boxes moist for several days, then allow it to harden for two weeks. Remove the boxes and, with a heavy hammer or sledge, break the concrete blocks. Which is harder to break to pieces?

†*Clay* is composed of the metal aluminum combined chemically with silicon, oxygen, and water. It is used in making tile, sewer pipe, brick, pottery, and dishes. Only pure clay free from iron compounds is used for fine pottery and china.

Special Reports. In what parts of the United States are fine china and pottery made? Describe the processes of making them.

†*Asbestos* (Fig. 184) is a mineral which is not affected by heat. Its fibers bend easily without breaking and have a silky luster. Some is white, some is green, and some is gray. It is widely used as a packing around steam-engine boilers and in mats for laboratory use. Fireproof paint is made by mixing ground asbestos with building paint. Thread made of asbestos fibers is woven into fire-fighters' clothing, as well as lamp wicks, cooking mats, and curtains for theaters.

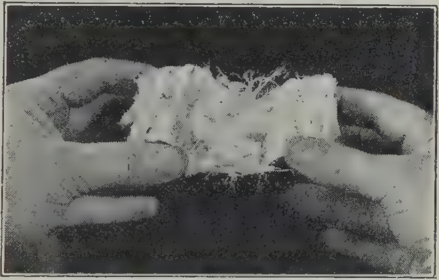

FIG. 184. ASBESTOS
Note the fibers

219. The building stones. The earliest stone houses were caves. Since primitive man had no implements with which to hollow out the rock, he occupied such natural caves as he was able to find. Many thousands of years passed before men learned to cut stones for buildings (Fig. 185). The wonderful buildings that still remain from the times of ancient Greece, Rome, and Egypt were built of blocks of cut stone. In modern times, however, concrete has almost entirely taken the place of stone blocks for buildings. Building stone now finds comparatively little use except for facing steel and concrete structures and for especially beautiful buildings, such as cathedrals (Fig. 186).

*When men began to learn how to use stone for buildings, they experimented with various kinds. Some kinds of stone proved unsuitable because they weathered (see page 291) too rapidly, because they would crush under

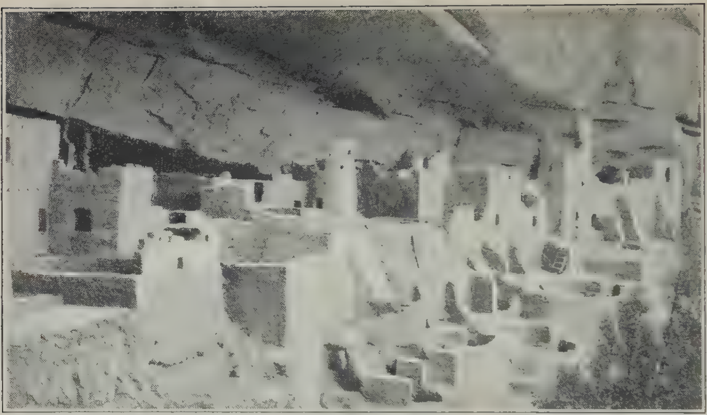

Fig. 185. Cliff Dwelling at Mesa Verde National Park, Colorado

Stone dwellings like these were built in the mouths of caves high up in the cliffs, by a race of people who lived in the great Southwest and disappeared before the white men came to America. This palace, the largest of all the ruins found, has about two hundred rooms. The stones were cut by hand and are held together in the walls by adobe mortar

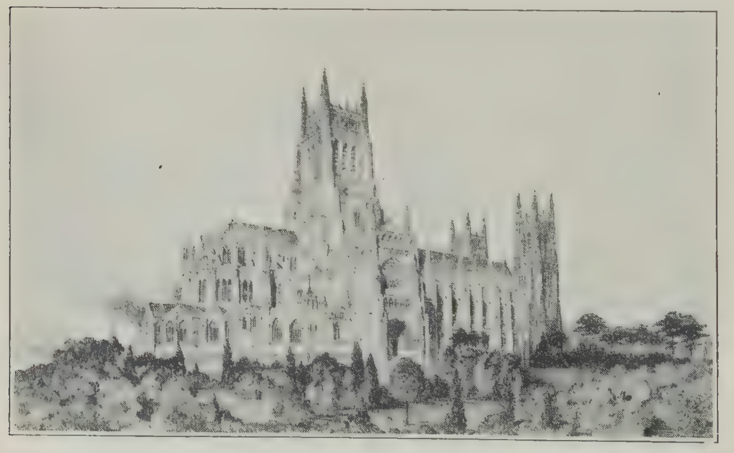

Fig. 186. Cathedral of St. John the Divine in New York City, as it will look when Completed

great weights, or for other reasons. At present only five natural stones find much use in building: limestone, sandstone, granite, marble, and slate. Of these, limestone and sandstone are sedimentary (see page 302), granite is igneous (see page 304), and marble and slate are metamorphic (see page 304). Slate is used for roofs of buildings, but not for the walls as are the other four.

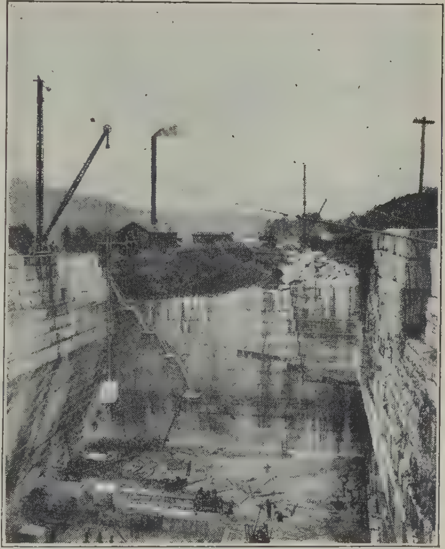

FIG. 187. THE CHEROKEE QUARRY, TATE, GEORGIA

A great marble block is being hoisted. (Courtesy of the Georgia Marble Co.)

Limestone is a mineral formed from the shells of animals that lived ages ago in the ocean. These shells collected in strata which slowly hardened into limestone. Limestone is found in various parts of the Union, though the finest deposits are in the Middle West, Kentucky, and Vermont. Most of it is used locally, but the finest limestone is shipped to all parts of the country. Limestone is white, gray, green, brown, and other shades. Besides its use for buildings, it is used in making fertilizers[1] and glass and in building railroads and highways.

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[1] *Fertilize* (fer′ti lize): to make fertile. *Fertilizer* (fer′ti li′zer): that which fertilizes; usually a substance that aids the growth of plants.

Sandstone is less hard and is more easily weathered than limestone. It is widely distributed through the United States, some of the best being in the states of New York and Ohio. It is found in many shades. Some kinds are much harder and hence weather more slowly than others.

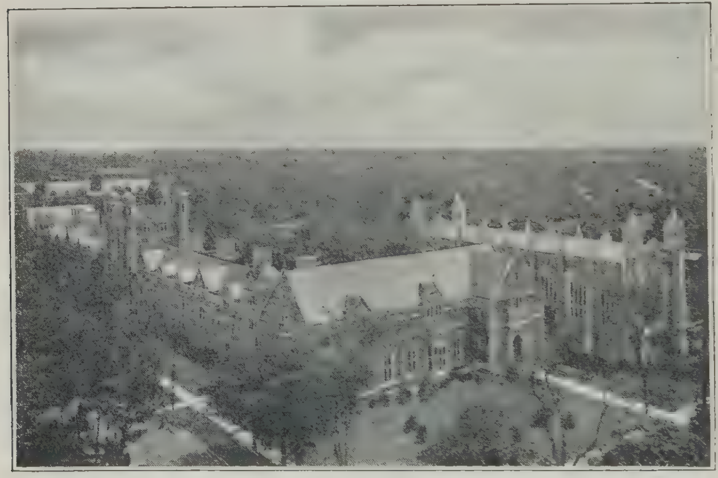

FIG. 188. ONE OF THE MOST BEAUTIFUL COLLEGE BUILDINGS IN AMERICA

It is built of granite trimmed with limestone. The roof is of slate

Marble is limestone which has been changed by heat and pressure to a crystalline rock. Marble is white, gray, black, and various shades of pink, red, brown, yellow, and green. The pure-white marble is used for monuments and statues, but it tends to weather easily (see page 291) and become dark. Most of the marble comes from Vermont, though valuable deposits are also found in Tennessee, Georgia, Arizona, and California (Fig. 187).

Granite weathers and erodes (see page 291) less rapidly than any other building stone. It is found in many colors. It is found at or near the surface of the ground in New England; it also forms the core of many mountains in the West. It is widely used in buildings and monuments (Fig. 188).

Can you explain why most of the granite is quarried in the Atlantic states?

Special Report. How many uses of the four building stones — granite, marble, limestone, and sandstone — can you find in your neighborhood?

220. Glass. Have you ever thought how hard it would be for us to get along without glass? What should we do without glass jars, bottles, and dishes? Yet in the days of Egypt only the rulers and the wealthiest people could afford to own even a few rude bottles. How would it seem to have no panes in our windows? Yet only a few hundred years ago there were no glass windows.

*Glass may be considered one of the treasures from the earth's storehouse, because all the substances of which it is made come from within the earth; in fact, certain igneous rocks (see page 304) are very much like glass, one being called volcanic glass. All glass is made by heating sand to a high temperature with certain compounds of some of the metals. Thus sand heated with compounds of sodium and calcium produces window glass and bottle glass; sand heated with compounds of potassium, lead, and aluminum produces other kinds of glass. The sand and the metal compounds are heated in a furnace until they melt, forming a thick liquid. This half-liquid glass is blown against the inside walls of molds, forming bottles, lamp shades, and similar objects. In the more modern factories compressed air is used in blowing the glass, but in some of the plants men blow the glass even yet.

Special Report. Describe the manufacture of window glass.

A large percentage of all injuries received in automobile accidents is caused by the shattering of the windshield and the consequent cutting of the people by the broken glass. To prevent such injuries some automobile manufacturers have recently equipped all their automobiles with windshields made of glass that will not shatter (Fig. 189). This glass consists of three layers, the two outer layers being plate, or sheet, glass between which is a layer of some substance like celluloid. The three layers are laid carefully together and are then put through seventeen different processes. Even if a person were thrown through such a windshield he would not be so likely to be cut as with an ordinary broken windshield, since the glass bends more readily.

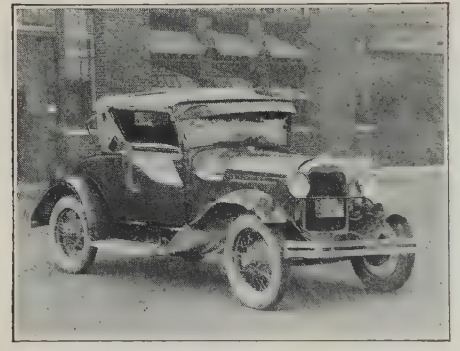

FIG. 189. A SHATTER-PROOF WINDSHIELD

This windshield merely cracked, but did not shatter as an ordinary glass windshield would have done

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. Man secures from the earth stores of raw materials and other materials which furnish ____.
2. Geysers are most likely to be found **in great river valleys on ocean beaches in volcanic regions near artesian wells near lakes and swamps.**

3. All coal beds were once under water.
4. The most useful product obtained from petroleum is **paraffin** **fuel oil** **benzine** **kerosene** **gasoline.**
5. Mercury is a rock, but is not a mineral.
6. The most valuable metal is gold.
7. A metal which is known to be constantly giving off energy is **gold** **silver** **copper** **tin** **mercury** ____.
8. The most valuable artificial rock used in the construction of great buildings, dams, and the like is **limestone** **concrete** **granite** **asbestos** **slate** **clay.**
9. The natural building stone which resists weathering and erosion best is **granite** **concrete** **slate** **limestone** **marble.**
10. All glass contains **clay** **aluminum** **sand** **soil** **lead.**

CHAPTER XX

KEEPING TRACK OF TIME AND PLACE

Some Questions this Chapter Answers

What did primitive peoples know about the cause of the seasons? What causes the seasons? Why is summer warmer than winter? How do we keep track of the hours? What is meant by "sun time"? What is standard time? Why is standard time convenient? What is daylight saving? What are some of its advantages? How do we keep track of dates? How are places located on the earth?

221. Early ideas regarding the seasons. Primitive peoples did not know enough astronomy to enable them to invent an accurate calendar. Of course they noted the regular return of full moon and the succession of the seasons. Thus, the Indians would locate some event by saying that it had occurred "three moons" before, or they would give the age of a child as "two summers."

Long before men became civilized, however, they noted that the length of daylight changed from moon to moon. They came to know that daylight lasted longer than the darkness during the warmer period, or summer, and that the darkness lasted longer than the daylight during the colder period, or winter. They were unable, of course, to account for these phenomena and consequently invented strange and interesting myths to explain the "longer" and "shorter" days (see pages 333 and 335).

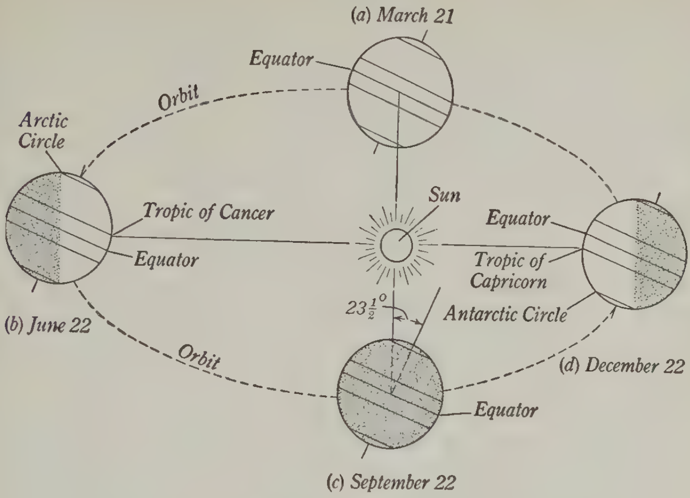

FIG. 190. DIAGRAM SHOWING THE CAUSE OF THE SEASONS

The tilt of the earth's axis to the plane of its orbit causes the seasons as the earth revolves round the sun.

HOW ONE INDIAN TRIBE TRIED TO ACCOUNT FOR THE SEASONS

Ojeeg was a little Indian boy who longed to be a great hunter like his father. But at that time all the days were short, and there was always ice and snow. Ojeeg could not stay out hunting long because of the severe cold. So he asked his father to use magic and make summer for him.

Big Hunter loved his little son and longed to please him. He secured the aid of his friends, Otter, Beaver, and Badger. They all decided they must make a hole in the sky. After traveling to the top of a high mountain, Otter made a great jump but he could not reach the sky. Next Beaver tried, but he also failed. Then Big Hunter tried another plan. First he climbed on the strong shoulders of mighty Badger and then leaped with all his strength. He touched the sky! A second and a third time he jumped, and finally the sky opened, allowing sweet summer to rush through. Little Ojeeg hunted and fished as much as he pleased, and since then the long warm days of summer come every year.

222. Why we have the seasons. It is only within the last few hundred years that the astronomers have known that the seasons are due to the fact that the earth's axis tilts at an angle of $23\frac{1}{2}$ degrees from the perpendicular to the plane of its orbit (Fig. 190).

*If the earth's axis were vertical to the plane of its orbit (that is, if the earth's axis did not tilt), there would be no "longest" and "shortest" days in the year; there would be no seasons, because the direct rays of the sun would always strike the equator; every spot on the earth would then have twelve hours of daylight and twelve hours of darkness *every* day in the year (Fig. 191).

*Since the earth's axis tilts away from the perpendicular to the plane of its orbit, there are only two days in the year, March 21 and September 22, when its axis is not tilted either toward the sun or away from it (Fig. 190). On these two days the direct rays of the sun fall on the equator, with the result that every spot on the earth has twelve hours of daylight and twelve hours of darkness. For this reason March 21 is called the *spring equinox*[1] or *vernal equinox*, and September 22 the *fall equinox* or *autumnal equinox*.

*As the earth travels round its orbit after March 21 the upper end of its axis points more directly toward the sun from day to day. The direct rays of the sun, therefore, strike farther and farther north of the equator. On June 22 the earth has reached the point in its orbit where its axis points most directly toward the sun (Fig. 190). Since the axis tilts at an angle of $23\frac{1}{2}$ degrees, the direct rays of the sun now strike $23\frac{1}{2}$ degrees above the equator. The sunlight reaches $23\frac{1}{2}$ degrees beyond the north pole, throwing all the arctic circle into the sunlight while all

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[1] *Equinox* (e′kwi noks): from two Latin words meaning "equal" and "night."

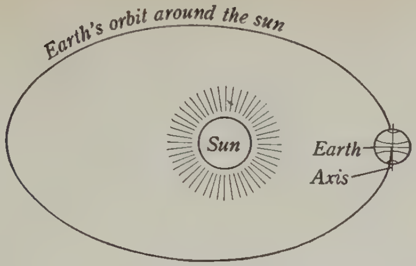

FIG. 191. THIS EARTH WOULD HAVE NO SEASONS

If the earth's axis were vertical to the plane of its orbit, there would be no seasons. Why?

HOW THE ANCIENT GREEKS TRIED TO ACCOUNT FOR THE SEASONS

Proserpina was the little daughter of Ceres, the goddess of agriculture. One day while she was picking flowers in a meadow King Pluto carried her off to his home in the regions of darkness beneath the earth. Proserpina was very unhappy in this gloomy place. She vowed she would eat no food until Pluto set her free.

Ceres hunted for her child all over the earth. Finally she resolved that no plant should grow on the earth until Proserpina was restored to her. At last men and beasts all over the earth were suffering so much from lack of food that the gods sent Mercury to ask Pluto to give up Proserpina. Pluto unwillingly consented, and Proserpina was sent home to Ceres.

Ceres was very happy to have her daughter back again, yet she felt that something was wrong. "Did you eat nothing in King Pluto's palace, my daughter?" she asked. Then Proserpina confessed that on that very morning she had taken a little bite of pomegranate and had swallowed six of its seeds.

"Oh, misery!" wailed the poor mother. "Now you must spend a month with King Pluto every year for every seed you have eaten. I shall have you but half the time."

So every year Ceres and Proserpina rejoice in the sunshine for six months and all the earth flourishes, but poor Proserpina must spend the rest of the year below the earth in the Kingdom of Darkness.

the antarctic circle is in darkness (Fig. 190). This date is called the summer solstice.[1] The imaginary [2] circle round the earth, $23\frac{1}{2}$ degrees north of the equator, where the direct rays of the sun fall on June 22, is called the tropic of Cancer. On June 22 every spot on the earth north of the tropic of Cancer has more than twelve hours of daylight. We are now having summer. On the same day every place south of the tropic of Cancer is having less than twelve hours of sunlight.

*As the earth continues round its orbit its axis gradually points less directly toward the sun. Day by day the direct rays of the sun move south from the tropic of Cancer, until on September 22, when the earth's axis is pointing neither toward nor away from the sun, the direct rays of the sun rest again on the equator (Fig. 190).

*The earth travels on. The northern end of its axis now tilts slightly away from the sun. The direct rays of the sun leave the equator and continue to travel gradually farther south, until on December 22 they have reached their most southern point. On this date the northern end of the earth's axis tilts directly away from the sun. The sun's direct rays now strike the earth $23\frac{1}{2}$ degrees south of the equator, drawing round the earth an imaginary circle called the tropic of Capricorn. All the antarctic circle is now in sunlight and all the arctic circle is in darkness. Every spot on the earth south of the tropic of Capricorn on December 22 (the date of the winter solstice) has more than twelve hours of daylight and fewer than twelve hours of darkness. In Argentina and South Africa, therefore, people have summer when we are having winter. Thus their seasons are always the reverse of ours.

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[1] *Solstice* (sol′stis): from two Latin words meaning "sun" and "stand."

[2] *Imaginary* (i maj′i na ry): existing only in the mind.

*As the earth continues in its orbit the direct rays of the sun gradually travel north toward the equator and the tropic of Cancer, and the seasons are repeated.

> Why is it that the people of Vermont associate snow with Christmas and the people in Rio de Janeiro, Brazil, do not? How is it possible for boys in Alaska to play baseball at 11 P. M. on June 22? Norway is called the Land of the Midnight Sun. Explain. How do you account for the fact that there are six months of daylight followed by six months of darkness at the north and south poles? Are the two poles having daylight at the same time? Why is it more correct to say that we live *north* of the equator than to say that we live *above* it?
>
> The axis of Mars tilts at nearly the same angle as the axis of the earth; Jupiter's axis scarcely tilts at all. Would either Mars or Jupiter have marked seasons? Would both? If either has marked seasons, would these be longer or shorter than the earth's? Why?

*The imaginary circles drawn on the earth by the sun's rays during the year mark the boundaries of the zones. Thus the direct rays of the sun pass back and forth across the torrid zone, between the tropics of Cancer and Capricorn. The arctic and antarctic circles include all the places on the earth which at some time in the year can have more than twenty-four hours of continuous daylight or darkness. Places in the temperate zones never have the direct rays of the sun and never have twenty-four hours of daylight or darkness at a time.

223. Why is summer warmer than winter? The earth's orbit is not *quite* a perfect circle (see page 333) but is slightly elliptical. The sun, moreover, is not *exactly* in the center of it. Fig. 190, p. 333, shows this last fact, but shows the sun to be much farther away from the center of the earth's orbit than is actually the case. But Fig. 190 shows us also a surprising fact. We who live in the north-temperate zone are actually *farther* from the sun during our summer than during our winter. How, then, can our summers be warmer than our winters? There are two reasons: (1) we actually receive more light and heat from the sun during the summer, because the sun's rays strike more directly down upon us than in winter; (2) the sun is pouring down upon us its heat and light for so many more hours every day during the summer than during the winter.

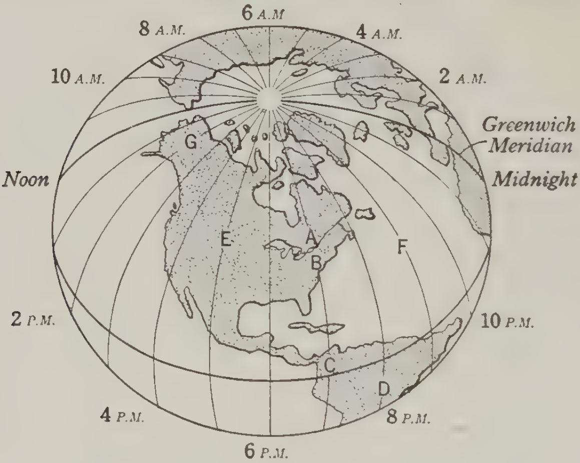

FIG. 192. HOUR CIRCLES ON THE EARTH

†If the earth always kept the same side toward the sun, like Mercury (see page 262), the time of day at any spot on the earth would never change. Any spot on the earth would always be having either unchanging daylight or unchanging darkness, year after year and century after century. But the earth does rotate, and this rotation causes sunrise, noon, sunset, and night.

224. *How we count the hours. For convenience both in locating places on the earth and in reckoning time the equator is divided into exactly three hundred sixty parts called degrees. Each degree is further divided into sixty minutes, and each minute into sixty seconds. These minutes and seconds are parts of a circle, not minutes and seconds of time. Imaginary lines are drawn on the earth, which run north and south through the degrees, minutes, and seconds, and end at the poles (Fig. 192). These imaginary lines are called meridians of longitude.

*The meridian of longitude which passes through Greenwich is called the *zero meridian* or *prime meridian.* Since there are exactly twenty-four hours in a day, the earth rotates one twenty-fourth of 360 degrees, or 15 degrees in one hour; so the meridians every 15 degrees apart, starting at the prime meridian, are called *hour circles,* because each of these twenty-four-hour circles has sunrise exactly one hour later than the hour circle east of it (Fig. 192).

Cities A, B, and C (Fig. 192) are having sunrise exactly at the same instant, but D had sunrise an hour before cities A, B, and C, and city E will have sunrise two hours after they have it. Why? If it is exactly 10 A.M. at city E, what time is it at F and G?

225. *Sun time. The exact hour of the day at any point on the earth is the "sun time." Noon at any place is the exact second in the day when the sun is nearest overhead. All points on the same meridian are having noon at the same instant. At that instant it is afternoon at all places east of that meridian, and forenoon at all places west.

Thus because Portland, Oregon, is west of New York the sun time there is later than the sun time in New York. For this reason people in Portland, Oregon, may know before 2 P.M. the results of a World's Series baseball game which did not begin in New York until 2.30 P.M. of the same date.

Why do afternoon newspapers in San Francisco contain more European news than afternoon papers in Boston?

226 †Standard, or railroad, time. If we tried to keep our watches exactly correct by sun time we should have to be putting them ahead whenever we went a few miles east and back whenever we went west. To avoid confusion and bother of this sort the civilized nations in 1884 established standard time. According to this plan time belts about fifteen degrees wide were established round the earth with each of the hour circles in the middle of the time belt.

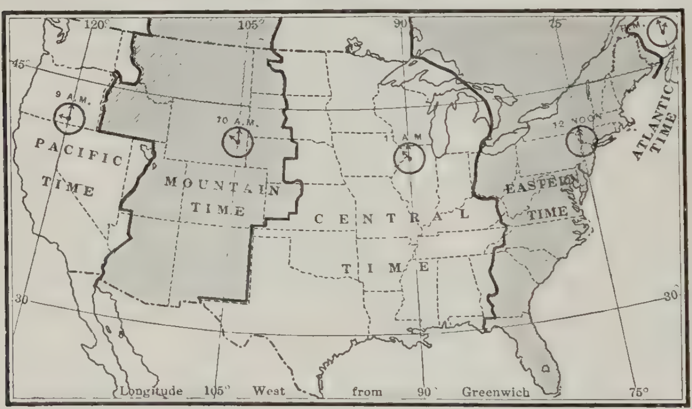

FIG. 193. THE STANDARD-TIME ZONES OF THE UNITED STATES

When it is noon, standard time, where you live, what is the standard time at Boston? Los Angeles?

†The United States is marked off into four of these belts, each roughly fifteen degrees across. For convenience every place within any time belt has the same standard time

(Fig. 193). Thus New York and Pittsburgh have the same standard time, though Pittsburgh's sun time is considerably later than New York's. Chicago's standard time is exactly one hour slower than New York's and Pittsburgh's. If you were traveling from Chicago to New York you would have to put your watch ahead only once, and that would be when you crossed into the Eastern Standard Time belt.

Special Report. What is the International Date Line? Why was it established? How is it used?

227. Daylight saving. Many of you know that the city you live in has "city time" or "fast time" and that this is one hour ahead of your standard time. "City time" is "daylight-saving time." More than one hundred and fifty years ago Benjamin Franklin suggested the idea of daylight saving. It is only within the last few years, however, that daylight saving has been established in various parts of this country. The purpose of daylight saving is to start the working day an hour earlier so that we can be through with the day's work and ready for recreation while there is still considerable daylight left. Thus in summer there is time for baseball, swimming, and other outdoor recreations between dinner and dark because we have added an extra hour of daylight to our waking day. To accomplish this some places keep the clocks one hour ahead of the standard time all the year round; in others the time is put one hour ahead of standard time in April and is set back again one hour in October.

In spite of considerable opposition to daylight saving, the idea is popular in many parts of the country.

Many of the ancient civilized peoples established calendars of their own to keep track of their historic dates.

There was the Egyptian calendar, the Hebrew calendar, the Chinese calendar, the Mohammedan calendar, and others (Fig. 194). No two of these began with the same year, because each people began its own calendar with some important date in its own history. All these calendars were more or less inexact because their astronomers did not have accurate instruments with which to make their astronomical measurements. In the first century before Christ, Julius Cæsar established the Julian calendar, making every year $365\frac{1}{4}$ days long. In the sixteenth century Pope Gregory XIII established the Gregorian calendar, which was more accurate than the Julian calendar. The Gregorian calendar was not adopted in England until nearly two centuries later, however, and it has been adopted in Greece and Russia only within very recent years. It is now used in this country and in most of the civilized world, but by no means in all of it.

FIG. 194. MAYAN CALENDAR STONE FOUND IN A RUINED TEMPLE

Courtesy of the American Museum of Natural History

Lately it has been proposed by Mr. Moses B. Cotsworth, a Canadian, that the calendar again be changed throughout the civilized world. With this "International Fixed Calendar" the year will consist of thirteen months of twenty-eight days each, making 364 days. The thirteenth month will be added between June and July and will probably be called Sol. Every year and every month will begin on Sunday, and thus every date will come on the same day of the week every year. All national holidays will be set on Mondays to allow the working people two successive free days. The three-hundred-and-sixty-fifth day will be "Yearday" between Saturday, December 28, and Sunday, January 1. The extra day in leap years will similarly be June 29, between Saturday, June 28, and Sunday, Sol 1. Easter will always be the same Sunday in April.

It is thought that everybody will derive some benefit from the new calendar, though those will gain the greatest advantages who are engaged in commerce and business. It will be easier to plan the monthly expenses both of business firms and of households when all the months are of the same length and have the same number of Saturdays. Why?

228. ***Locating places on the earth.** The meridians of longitude not only serve to determine the time but also help to determine the exact location of every place on the earth. They enable us to know how many degrees east or west of London any place is. But if we are going to locate a place *exactly* we must also know how many degrees north or south of the equator it is. For this purpose, with the equator as a starting line, imaginary circles called parallels of latitude are marked off on the earth in the same manner as the meridians of longitude, but running *east* and *west* round the earth. Places north of the equator are said to be in "north latitude"; those south of the equator, in "south latitude" (Fig. 195). Thus the north pole is 90 degrees north latitude, and the south pole 90 degrees south latitude. The longitude of the north and south poles is zero. Explain. In Fig. 195 the location of the ship at D would be 20° N. (latitude) and 30° W. (longitude).

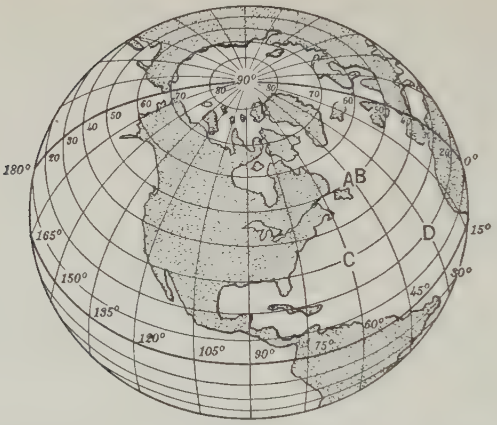

FIG. 195. PLACES ARE LOCATED ON THE EARTH BY LATITUDE AND LONGITUDE

How is the location of buildings in a city similar to this?

Ship A (Fig. 195) is in distress and sends out an "S O S" call by radio, giving its position as 45° W. (longitude) and 50° N. (latitude). Ship B catches the signal and sends back a message to A, stating that it is at 40° W. 50° N. and is hastening to the rescue. Does each boat know exactly where the other is? Can Ship B go directly to Ship A? Ships C and D also catch the distress signal, but they are too far away to help. Can you give the positions of Ship C?

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. The tilt of the earth's axis from the perpendicular to the plane of its orbit is **90° 23½° 45° 37½° 0°** ----.
2. There are seasons on the earth because of **the tilt of the earth's axis the rotation of the earth on its axis the**

fact that the earth is nearer the sun at certain times than at other times the tidal action of the sun and moon the daily changes in weather.

3. The two days during which there are twelve hours of daylight and twelve hours of darkness everywhere on the earth are June 22 and September 22.
4. On December 22 the vertical rays of the sun strike the earth at the ____.
5. The vertical rays of the sun never strike the earth farther north than the ____.
6. A year is very nearly 365 days $365\frac{1}{4}$ days $364\frac{1}{4}$ days 28 days 360 days.
7. When it is noon at London it is morning at Chicago.
8. When it is noon at Chicago it is afternoon at San Francisco.
9. When it is noon at a certain city it is forenoon afternoon yesterday the same hour tomorrow at another city exactly north of the first city.
10. We can locate a place exactly on the earth if we know its ____ and its ____.

SCIENTIFIC PUZZLES AND GAMES

Can you solve this problem?

Problem. Minnie is twelve years old now. Sue is six years older than Minnie, who is four years older than Emma. If Emma will be seventeen a year from now, how old was Minnie a year ago?

Which of the scientific attitudes (see pages 8–10) did you use in solving this problem?

UNIT IX. THE EARTH'S POPULATION

CHAPTER XXI

SOME PROBLEMS OF PLANTS AND ANIMALS

Some Questions this Chapter Answers

What are some of the substances that a plant must have in order to live? Can a plant live in one pot for a decade without having the soil changed? What is plant sap? How do plants secure water from the soil? What is chlorophyll? What are carbohydrates? What are the necessary parts of a living cell? What are the different processes related to plant food from its beginning until it is made into living material? How do plants grow? How are new plants made? Can protoplasm be frozen without being killed? How do plants and animals live through periods of great cold or great dryness?

229. Growing in a small home. The plant shown in Fig. 196 has lived almost all its life in the same small pot. It was placed in the soil of the pot when it was small. It has moved only when its home, the pot, was moved. We are told that the soil has not been taken from the pot in the ten years the plant has lived in it, and that little or no new soil has been added. Water has been frequently added to the soil, and sometimes in the water there were small amounts of substances containing nitrogen, iron, sulphur, potassium, phosphorus, and other elements which served as fertilizers.

The plant has increased greatly in size and weight during the years it has grown in this place, and its roots have grown until they are crowded in the pot. If the roots were placed end to end they would reach many times as far as the plant is high. If all the leaves were placed side by side they would cover an area hundreds of times larger than the area covered by the few leaves the plant had when it was young. The stem is thick and strong because of the wood it contains. The plant may have produced flowers and seeds from year to year and may possibly be the parent of many young plants like itself.

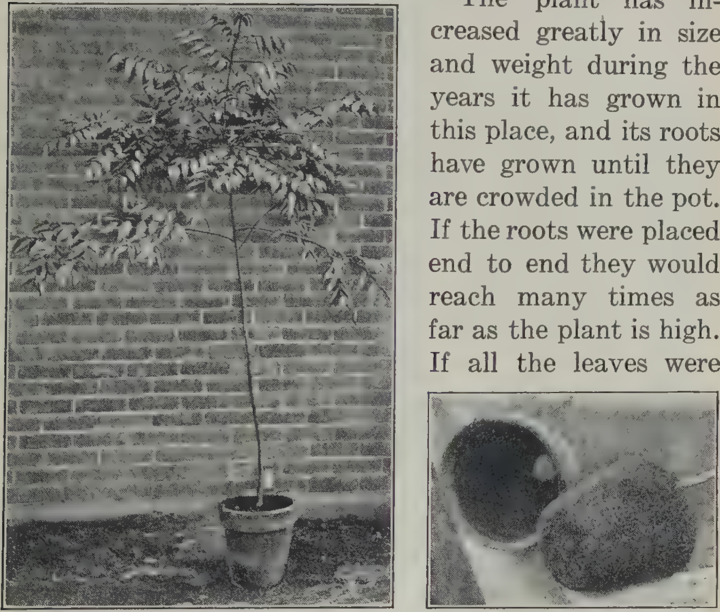

FIG. 196. GROWING IN A SMALL HOME

In the picture at the left is shown the tree which has grown for ten years in this pot. In the picture at the right the pot and the masses of roots of this tree are shown. How can a tree live so long in such a way and still be healthy?

The plant has a small home; it is not able to move to a new place; it has only a few cubic feet of soil, and this is crowded full by the mass of roots; it seems likely, however, that the plant can live for many more years in this same home if it has enough water. One cannot help wondering how such a plant can live in such a way (Fig. 196)?

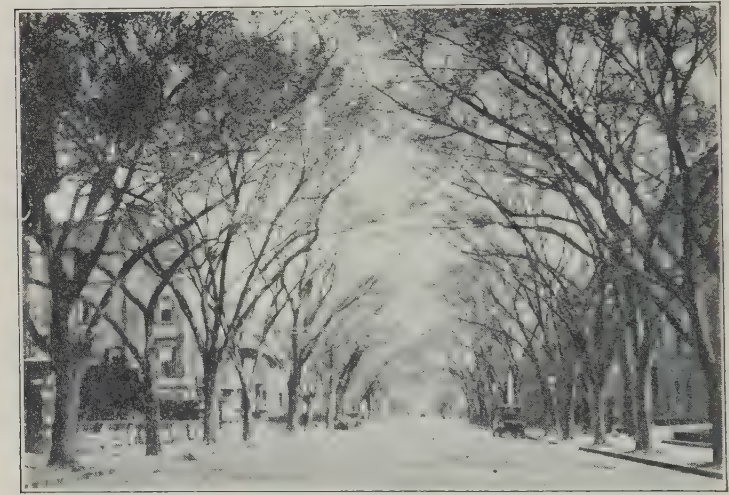

FIG. 197. ELM TREES GROWING UNDER DIFFICULTIES

These trees grow in one of the most attractive streets of Washington. D.C. They are many years old. Houses are built near them, and the gases from the city fill the air. The streets are paved, and there are sidewalks of cement. How can the trees secure water, light, and air? (Courtesy of the *American Forests and Forest Life*)

230. †A plant a kind of factory. In this book you have learned that the air contains carbon dioxide and other gases (Chapter IV). The soil contains water, and in the soil there are compounds that contain nitrogen, iron, sulphur, and many other chemical elements. These are the materials used in the living plant machine.

*We usually think of any factory as having the materials it is to use delivered to it by some kind of transportation lines. The plant factory has its own transportation system. It secures its water through the smallest divisions of its roots (Fig. 198). It carries the water from these divisions, which are called *root hairs,* into the larger ones, then through the stem into the leaves. Enough water remains in all parts of the plant to keep them moist. It is common to speak of the water in plants as sap. *Sap is the water in plants which has plant substances and materials from the soil dissolved in it.* Water is evaporated from the leaf surfaces. Indeed, in a growing plant evaporation from the leaves is almost always going on (see page 48). The amount of evaporation varies in different seasons and in different kinds of weather. It is common to speak of the upward current of water through plants and into the air as the transpiration[1] current. Transpiration really means breathing water into the air, although the plant is evaporating water and not breathing it.

*The surface of a leaf has special openings, or pores, through which carbon dioxide can go into the leaf. The carbon dioxide is readily dissolved by water. Thus the leaves secure a supply of materials from two sources: (1) the carbon dioxide from the air, and (2) water and dissolved substances from the soil. Water and carbon dioxide are not food for a plant. No matter how much of these substances a plant might have, it would starve and die if they could not be changed into things that would nourish it.

*Green plants are green because the leaves and often the twigs and smaller stems contain a coloring substance called chlorophyll. When the sun shines upon the leaves the chlorophyll absorbs energy from the sunlight. By means of this energy the carbon dioxide and water are changed into compounds (see page 51) which contain all three of the elements of which the carbon dioxide and water are composed — carbon, hydrogen, and oxygen. Not all the oxygen from these two substances is used in making food; some of it is set free and added to the air's supply of oxygen.

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[1] *Transpiration* (tran′spi ra′shun): exhaling or evaporating into the air.

Experiment 42. How can we take the green coloring matter out of a leaf? Place in a beaker half filled with alcohol the leaves of any common plants, such as grass, corn, or geranium. After an hour or more note the liquid and the leaves and explain what you observe.

*The compounds of carbon, hydrogen, and oxygen are finally made into sugars and starches. These can be used as foods by plants as well as by animals. The carbon-hydrogen-oxygen foods made from carbon dioxide and water are called *carbohydrates.*[1] *The process by which the plant factory makes carbohydrates from carbon dioxide and water, using the energy from the sun, is called photosynthesis.*[2] The carbohydrate foods may be changed still farther by having compounds of nitrogen, sulphur, iron, potassium, and many other elements added to them. When changed in this way they cease to be carbohydrates and become *proteins.*[3]

231. *How water gets into plants. How does water get into the roots? In Fig. 198, *A*, is seen one of the small roots of a mustard plant, showing the hairlike parts, or root

---

[1] *Carbohydrate* (kar′bo hi′drate): food consisting of the element carbon and the elements composing water, which are hydrogen and oxygen.

[2] *Photosynthesis* (fo′to sin′the sis): putting together by means of light; the action of green plants in making such foods as sugars and starches.

[3] *Protein* (pro′te in): complex foods such as are contained in meat, eggs, and parts of bread, milk, vegetables, and grains.

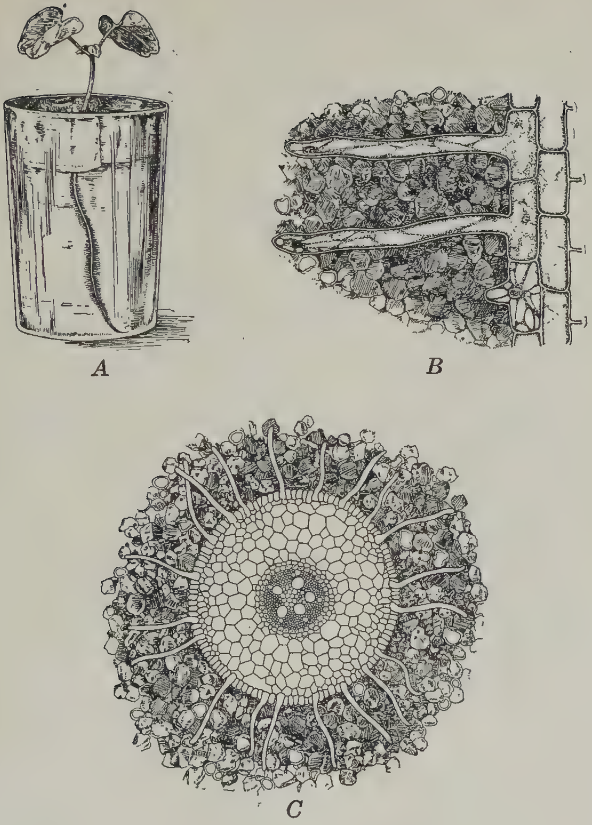

FIG. 198. ROOT HAIRS

A, a mustard plant grown from seed in a fold of blotting paper within a glass of water, the single root covered by root hairs; *B*, a small piece of a root showing the root hairs growing from the surface cells and reaching into the particles of soil; *C*, a section cut across a root showing root hairs going into soil all around hairs, which grow from its surface; in Fig. 198, *C*, is shown one of the roots with the root hairs extending from the surface of the root. The shaded material within the root hair (*B*) represents living material; the outside line represents the wall of the root hair. It must be kept in mind that the root hair is a tiny tube, and that a section across it would be circular. An experiment will help to explain the action of the water and the root hair.

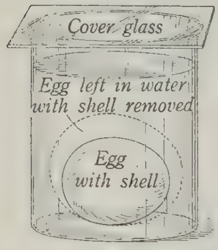

FIG. 199. SHOWING OSMOSIS WITH AN EGG

Experiment 43. Can an egg be made to show how water enters the root hair? The outer shell of a hen's egg is composed almost wholly of lime. Lime is readily dissolved by hydrochloric acid. Inside this lime shell is a tough membrane[1] which we will compare with the wall of the root hair. Dilute hydrochloric acid with water, then place an egg in a glass dish or beaker and cover it with the acid until the shell is dissolved (from ten to twenty minutes). When the shell begins to get soft, pour the acid out and pour water into the dish. Keep an egg of the same size, not treated in any way, but to be used for comparing any change in the size of the egg used in the experiment. Leave in the dish of water the egg from which the lime shell has been removed (Fig. 199). Cover the dish to prevent evaporation. Observe whether the egg changes in size, and whether there is any change in the amount of water in the dish. In half an hour and at later periods compare the two eggs in size. What conclusions can you make from the results?

*If a small hole had been carefully made in the egg membrane and a tall tube of glass had been tightly fastened in the hole, the water taken into the egg would have gone up into the glass tube. In fact, such an experiment (using an egg or any animal membrane, such as a pig's bladder, secured from a butcher's) can be made in which the water will rise several feet high in the tube (Fig. 200). When liquids are separated by a membrane such as the egg membrane or a pig bladder, they may pass through the membrane in both directions. The liquids continue to pass through the membrane until there is the same density on both sides of the membrane. Water passes to the inside of the egg much more rapidly than the contents of the egg pass outward. As the water passes inward the egg membrane is stretched until it is large and is tightly filled with the water and egg material. During this time not enough of what was in the egg passes out to equal the amount of water that passes in. The pressure inside the egg membrane therefore constantly increases. It is this pressure that causes the water to rise into the glass tube when a tube is attached within the egg membrane or above a membrane as in Fig. 200. This action of liquids in pass-

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[1] *Membrane* (mem′brane): a thin lining or covering.

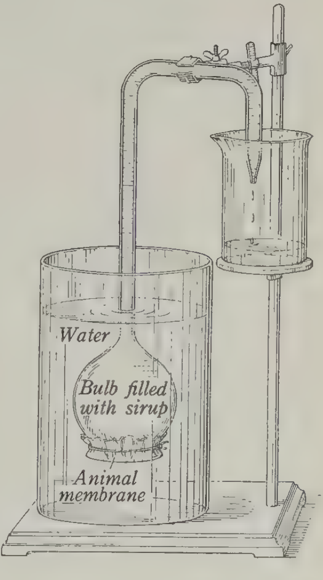

FIG. 200. HOW DOES WATER RISE IN PLANTS?

A membrane is fastened over the larger end of the glass tube. A thick sirup is within the tube. This is then placed in a dish of water. The liquids pass through the membrane, the water passing more rapidly than the thick sirup. What is the result?

ing through membranes is called *osmosis*,[1] and the pressure made as a result of osmosis is called *osmotic pressure.* In this same way water from the soil passes into root hairs. The osmotic pressure of the millions of root hairs on a plant helps to force the water upward through the plants. Besides osmosis, other factors help in producing the upward current of water in plants. These will be discussed later.

> ***Project.*** To see how high osmosis will cause water to rise in a glass tube. Set up an experiment like that in Fig. 200 except that the tube is not bent, and see how high you can get the water to rise in the glass tube. Is the rise sudden or steady? Keep a record of its rise for three days and record the final results.

*Evaporation from the leaves, which is constantly removing water from the upper parts of plants, helps to keep the water moving upward. The plant stem consists of many small tubes, so small that water tends to pass upward through them by what is known as *capillarity*.[2] All three processes — osmosis, capillarity, and evaporation — work to keep the stream of water going up through plants. It is thought, however, that even more factors must be found before science will have the full explanation of the rise of water to the tops of the tallest trees.

Experiment 44. Does water rise higher in small tubes or in large tubes? Secure some glass tubes with extremely small openings. Such tubes are called capillary (meaning "hairlike") tubes. Place the tubes upright, the lower ends in a beaker of colored water. Answer the question asked at the beginning of this experiment.

---

[1] *Osmosis* (os mo′sis): the passing of liquids through membranes.

[2] *Capillarity* (kap′i lar′i ty): the drawing of liquids into very small tubes or cracks.

232. *A plant is made up of cells. The root hair consists of the wall and the living material within it. This is commonly called a *cell* (Fig. 201). The living material is called *protoplasm.*[1] The protoplasm consists chiefly of two parts: the more solid central part (the *nucleus*[2]) and the softer, thinner, and more liquid part (the *cytoplasm*[3]). In the root-hair cell the cytoplasm just within the cell wall is somewhat more dense, forming an inside wall which in position is like the inside membrane of the egg. This cytoplasm wall is living. The outer cell wall is built up from the cytoplasm. Both plants and animals are made up of cells. In form and size cells vary greatly. Not all cells have the heavy outer walls, but all have the essential parts — the cytoplasm and the nucleus. A plant or an animal body may contain many millions of cells, or may consist of but one or a few cells.

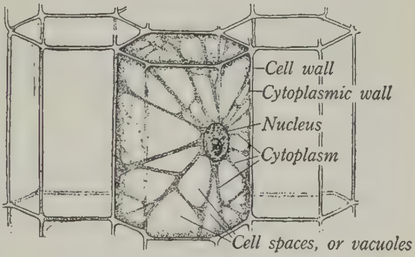

FIG. 201. A GROUP OF CELLS

Cells may have many forms due to their pressure against one another or to freedom from pressure. What parts are present in the cells here shown?

233. *Plants make use of foods. The protoplasm of cells is the really living part of all living things. It is that part of plants and animals which does all that is done by them. No one knows just what it is that makes living protoplasm different from protoplasm that is not living, but we know that the difference is great. The things which protoplasm does that are not done by other materials show some of the important differences between things that are alive and those that are not.

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[1] *Protoplasm* (pro′to plazm): the living material of plant and animal cells.

[2] *Nucleus* (new′kle us): the denser, usually central body of a living cell.

[3] *Cytoplasm* (sy′to plazm): the watery part of a living cell.

*In our study of the way green plants make food, we have seen one important thing that is done by protoplasm. Chlorophyll absorbs the energy from sunlight, but it is the living protoplasm that makes and changes the foods so that they can be used to nourish the plant. The foods are absorbed into this living protoplasm and become a part of it. When foods have been made, they must be changed into the proper liquid form for use by living things. This change is called *digestion.* Then the digested[1] food must be taken into and made a part of the living protoplasm. This process is called *assimilation.* Exactly what happens during assimilation is not known; it is known, however, that assimilation results in making more protoplasm or in replacing protoplasm that has been worn out through use, or in both. *Protoplasm, therefore, has the ability to replace itself by digesting and assimilating*[2] *food materials.* In doing this *protoplasm makes material that was not living into living material.*

234. Food materials and energy. The energy which makes possible any action of a plant or of any other living thing came at first from the sun, was secured through foods, and was stored for use in protoplasm. Part of the energy of sunlight goes to make food material. The more complex the foods, the larger the amount of energy used in making them. Even more is this true of protoplasm, for much energy is used in building protoplasm from digested foods. When protoplasm is used, its energy is set free. The protoplasm breaks into simpler substances; for example, water, carbon dioxide, and compounds of such elements as nitrogen, sulphur, and potassium. It is this released energy that makes all work possible, whether it is done by plants or by animals. It is to replace this broken-down protoplasm or to build new protoplasm that food materials are used. The products of broken-down protoplasm are disposed of and may later be used again in building new food material. As energy carriers, the same food elements may have been used by living things over and over, many hundreds of times. Thus carbon, hydrogen, oxygen, and other elements may be used again and again in the round known as the *carbon cycle*. The carbon, sulphur, nitrogen, or iron now possessed by a plant or animal may have been parts of hundreds of other plants or animals. The oxygen released during photosynthesis is added to the oxygen supply for all plants and animals. Chlorophyll as a manufacturing agent and sunlight as a source of energy are equaled in their wonderful work by the work of protoplasm itself.

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[1] *Digest* (di jest′): to make into liquids that can be used for food.

[2] *Assimilate* (a sim′i late): to take into as part of itself, as when digested food is made into living material.

235. †Cells grow and plants grow. There are two purposes for which cells take in digested food: one is to replace worn-out protoplasm; the other is to use this food in growth. That is, the cell enlarges as the result of its assimilation of the food. When a cell has thus increased in size and content it may divide into two cells, and each of these in turn into two others, and so on. Such division results in more cells and larger bodies, and this is called *growth*. Growth may be rapid or slow. Plants usually grow most rapidly in certain kinds of weather or in certain seasons. For example, a plant of Indian corn may grow several inches in length in a single day and night, and a squash plant has been known to grow over two feet in length in twenty-four hours. The ability to grow and to produce special parts of plants and animals is one of the most interesting and most important things that protoplasm can do.

236. †New plants from old ones. When cells of such a plant as that shown in Fig. 201 grow and divide to form new cells, there is an increase in the number of cells and in the size of the whole plant. The entire mass of cells, however, still forms but one plant. New individual plants are formed only when some parts of this plant are separated from the old plant and begin to grow separately. We could cut off a branch of a common geranium plant or a willow tree and, by planting it properly, could produce a new geranium or a new willow plant. This is the method commonly used when new plants of certain kinds are desired. In these cases the protoplasm of the cells is able to keep growing and to produce new roots, stem, and leaves; in other words, to produce a new plant.

†There are several other ways by which new plants are produced. The one most commonly noticed is by seeds. Flowers are formed and, by means of special parts of the flowers, seeds are finally produced. Within each seed is a very small new plant which appears to be quite unlike the parent plant. In due time, however, if the seed is properly cared for, it may reproduce, that is, it may produce a new plant like the one that formed it. This production of new living things is called *reproduction*, which means producing again, or forming new living things like the old ones. It is clear that this action of living things (that is, *reproduction by living protoplasm*) is of the greatest importance. Without some such process all life would be stopped with the death of the plants and animals now living.

*Not only does the protoplasm of plants produce seeds, but food material is stored in the seed and later used by the young plant when it starts to grow. This device for giving a new plant a start in life is most helpful to it. It is this excess food material stored in the seeds that makes some plants so useful to human beings.

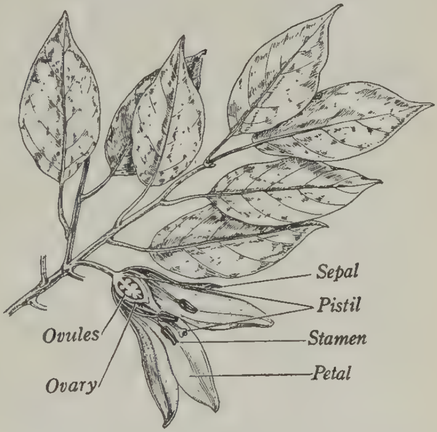

FIG. 202. A TWIG WITH A FLOWER

A complete flower has four parts: all the sepals together are known as the *calyx*; all the petals together are known as the *corolla*; next are the *stamens*, in the tips of which the pollen grains are formed; and in the center is the *pistil*, in the base of which the young seeds are formed

237. Flowers, seeds, and fruits. Flowers and seeds are found in so many varieties that even those students of science who give all their time to studying them cannot know all the varieties. The purpose of flowers is to produce seeds for reproduction. Since seeds produce new plants, it is clear that flowers and seeds are very important in plant life. They are important, too, because they provide food for many animals.

*The essential structures of a flower are (1) the central part or *pistil* (Fig. 202), in which are one or more *ovules* ("little eggs"), and (2) the *stamens*, which stand next to the pistil and in which the *pollen* is formed. The enlarged part of the pistil is called the *ovary*, since the ovules develop within it. It is in the pollen that the male cells develop. One or more pollen grains may fall upon the tip of the pistil, and from this pollen grain may grow a small tube in which the male cells are carried to the egg (or female) cell, which is within the ovule. There are other special parts and processes that are related to the forming of seeds. These are more fully presented in a later study, *biology*; that is, the study of life.

*The new cell that is formed when the male cell and the female cell have united grows and becomes the new plant. It is still within the ovule. The ovule wall may become hard and dry, as is true in many ripe seeds, or it may become a pulpy[1] fruit, or the whole pistil and sometimes the flower stem itself may become a pulpy fruit. Whatever parts ripen with the seed are called the fruit. For example, in an apple the ovules ripen into the shining seeds found in the middle, the wall about the ovules becomes the core of the apple, the outer part of the pistil becomes the inner part of the fruit, and most of the apple is the swollen lower part of the green outer leaves of the flower, whose withered tips are seen at the blossom end of the fruit. In the strawberry the tip of the flower stalk has pistils all over it. As the seeds ripen, this tip swells upward between the seeds. The seeds are in small pockets in the ripening stem tip. Thus the ripe strawberry is the enlarged stem tip with the seeds.

*A large part of our food comes from the different kinds of plant food stored by the plants in connection with their seeds. All the grains — wheat, corn, oats, barley, rye, and rice — are valuable to us because of food stored within the seed round the young plants. The nuts, such as walnuts, almonds, pecans, and filberts, have rich foods within the young plants themselves. The young plants are inclosed by the hardened skin of the ovule, and this in most parts by a wall made from the pistil. Tomatoes, apples, peaches, melons, oranges, and berries are valuable to us because of the plant food stored outside the seeds.

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[1] *Pulp*: a soft, moist mass. *Pulpy* (pul′py): pulplike, full of pulp.

238. Working and resting. Living things do not work all the time. Protoplasm, the living cells, the whole plant body, may work for a shorter or longer period, but they also rest for shorter or longer periods.

During the night the green plants are not making carbohydrates. At this time, too, much smaller amounts of water are carried upward through plants. The plant's protoplasm may, however, assimilate more food during the night than during the day. In some kinds of plants it is known that increase in the length of the twigs and leaves takes place more at night than by day. Usually, however, the night is a period of relative inactivity[1] of protoplasm compared with the day, though if all action of the protoplasm should stop, life itself would be stopped.

*The most easily noted resting stages occur during winter or during a long dry period. The leaves may drop from living plants such as trees and shrubs, and for half a year or more the whole plant may seem as if it were dead. When favorable seasons return, the inactive[1] protoplasm begins work, new leaves are produced, new growth is made, and flowers and seeds are produced. The plant then accommodates, or adjusts, itself again to another coming period of cold or dryness and another period of rest and dormancy.[2] These long periods of rest and inaction are during winter or prolonged dry weather; that is, they are related to seasons and climates. The fact that the plant is doing little or nothing during these periods means that at these times the protoplasm transforms little energy. Moreover, during these periods any food that may be used by the protoplasm comes from the plant's stored supply. Plant roots, stems, and seeds may remain dormant for several years and then grow when favorable conditions are provided. The seeds of some plants may be kept for many years, with the new plants within still living and ready to grow if they are given favorable moisture and temperature.

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[1] *Inactive* (in ak′tiv): not active. *Inactivity* (in ak tiv′i ty): the state of being inactive.

[2] *Dormancy* (dor′man sy): a condition of prolonged quiet and lack of action; state of being dormant.

*In the dormant condition protoplasm can live through such extremes of heat and cold as could not possibly be endured if these extremes should suddenly come during the active growing season. Seeds can be frozen slowly, or may be heated slowly to the temperature of boiling water, and still grow if they are quite dry and if all changes in temperature are made slowly.

*Protoplasm, therefore, commonly has *periods of rest* and *periods of action*, and during rest *can withstand wide extremes of temperature.*

*Animals, like plants, have periods of activity and dormancy. In dry regions and during the long winter periods of other regions many kinds of animals cease their common work of getting food, caring for their young, playing with their kind, or fighting their enemies. This dormancy is called *hibernation.* Snakes and lizards and many other animals go into holes where freezing temperatures either do not occur or else occur very slowly. Frogs (at least some kinds) dig deeply into the mud at the bottom of ponds and lakes and either do not freeze or else freeze and thaw slowly. Ants and many other insects dig into wood or the earth and pass the winter in a dormant condition, sometimes frozen. Woodchucks go down into their bur-

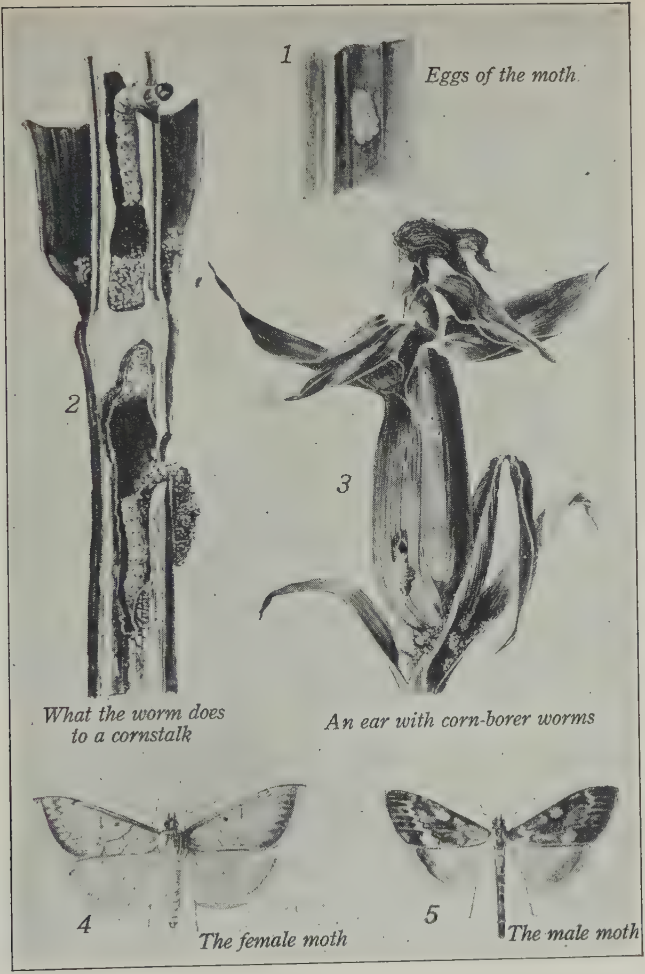
1
Eggs of the moth
2
What the worm does to a cornstalk
3
An ear with corn-borer worms
4
The female moth
5
The male moth

FIG. 203. FOODS FOR PLANTS AND ANIMALS

The life cycle of the European corn borer. Each living thing lives on something else. Can you explain how the corn borer depends upon photosynthesis? (Photograph by Bureau of Entomology) rows, and bears go into hollow logs or stumps or into caves and remain dormant until spring approaches. Bats hang by their claws in caves or hollow trees.

> *Special Report.* How many wild animals do you know? Ask them the question "Do you have a long period of dormancy, and if you do, where and how do you spend it?" Then watch and read to see if you can learn the answer to this question.

239. *Foods for plants and animals. It is not hard for one to trace all foods back to their source (Fig. 203). We eat some beef or mutton, some fresh beans, a salad of lettuce, some bread and butter, drink a glass of milk, then finish with some toast and honey. Our hunger for food is thus satisfied. The needs of our protoplasm are cared for, and our bodies are thus kept in working order. The cattle that produced the milk, butter, and steak ate grass and grain. The plant factory, by using the sun's energy which was absorbed by chlorophyll, produced the food for the cattle or sheep (Fig. 204). The lettuce is the leaves of a plant. The beans, made possible by the work of chlorophyll, might have been used to produce new plants. The old plant made protein food from its carbohydrates and stored it in the beans. The toast was made from bread which was made from the grains, or seeds, of the wheat plant. The honey was prepared from the nectar[1] produced in flowers. The nectar attracts bees, and while they are getting the nectar the bees help the plant by spreading the pollen to develop the seeds for new plants. The sweet nectar is made by plants from carbohydrates made by photosynthesis. *The work of green plants is the foundation of the world's food supply.*

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[1] *Nectar* (nek'tar): the sweet liquid found within many kinds of flowers.

Special Report. Prepare a diagram of a day's diet and show the sources of the foods, going back to the plants which are the foundation of all the foods included.

240. *Summary on protoplasm. Protoplasm is living substance. Its essential parts are the cytoplasm and the nucleus. The outer part of the cytoplasm produces the cell wall. The cell includes the wall, the cytoplasm, the nucleus, any included water or cell sap, air spaces, and any unused food or other substances that may be contained.

FIG. 204. HERDING SHEEP IN PALESTINE

Where plant food is scarce animals must make long journeys to get enough

*Protoplasm has the ability to digest and assimilate food material. By these processes it can replace any part of itself that may have become worn out and it can produce new protoplasm. Protoplasm can produce new cells, and by so doing it causes growth. Protoplasm can produce cells with which to reproduce plants and animals.

Protoplasm and the bodies built by it have periods of action and periods of rest. Protoplasm stores and releases the energy by means of which all animal and plant work is done.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. Water enters a plant through its **leaves** **root hairs** **flowers** **stem** **bark.**
2. Plants receive the energy by which they manufacture their food from **chlorophyll** **sunlight** **soil-water** **air** **fertilizers in the soil.**
3. Select from the following the word that does not belong with the rest: **sugar** **carbohydrate** **carbon** **food** **hydrogen** **osmosis** **starch** **oxygen.**
4. If liquids were unable to pass through membranes there could be no **photosynthesis** **osmosis** **chlorophyll** **energy** **evaporation.**
5. With the aid of sunlight green plants manufacture carbohydrates from carbon dioxide and ____.
6. Every living cell must contain cytoplasm and a wall.
7. Living material can be made from nonliving material only by the action of ____.
8. Food is stored in seeds in order to serve as food for human beings.
9. Select from the following the word that does not belong with the rest: **flower** **root** **pistil** **stamen** **ovules** **pollen** **egg cell.**
10. Plants and animals are most active during very cold weather.

CHAPTER XXII

STRUCTURE, HABITS, AND USES OF PLANTS

Some Questions this Chapter Answers

Can many kinds of leaves be found on the same tree? Are leaves so placed on plants that all may secure sunlight? What are the purposes of plant stems? What gives the supporting strength to the stem of trees? How do the stems of vines secure their support? What plants show that stems and roots are used in food storage? What are the sources of cotton and flax fibers? How is wood pulp made and used? What other products of plant stems are in common use in homes and factories? What are dependent plants? How do they get their food material? How are yeasts used in making bread and alcohol? What is a mushroom, and how does it live? What are parasites? saprophytes?

241. Kinds and arrangement of leaves. The first business of a leaf is to make food materials, using the energy that chlorophyll helps it to get. To carry on this one business, there are very many kinds of leaves, there are many ways in which they are arranged on the stems and branches, and there is a good deal of variation in the form of leaves on the same plant (Fig. 205). The leaves of a plant may be large and few, as on corn, sunflowers, and beans; or they may be many and small, as on rosebushes, hedges, and spruce trees. The leaves may be undivided, as in

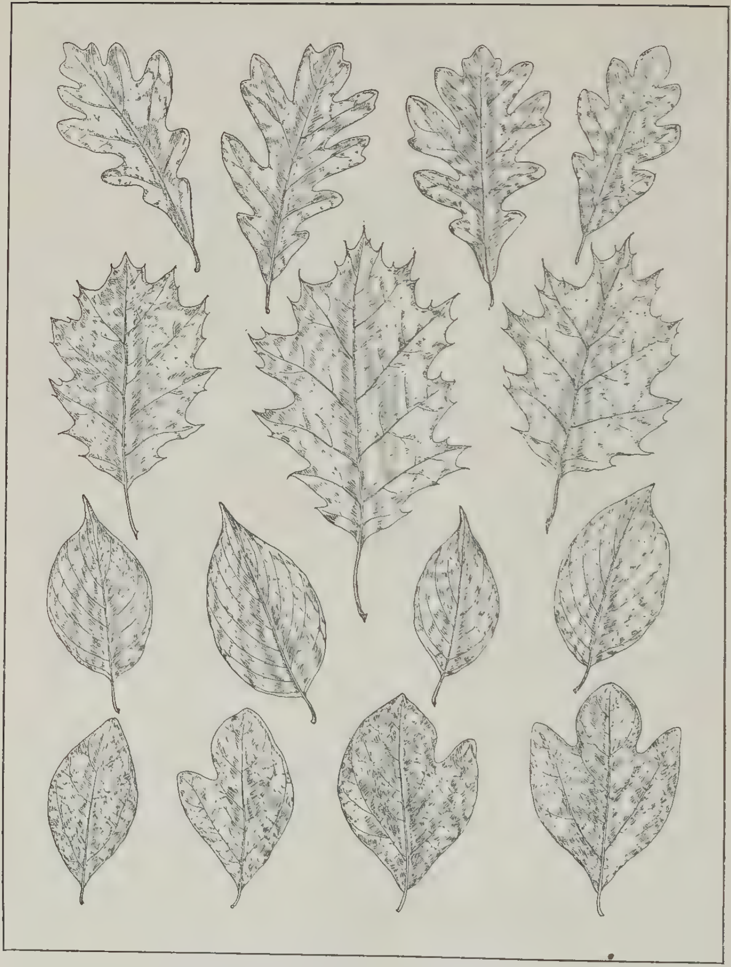

FIG. 205. HOW LEAVES DIFFER

The upper row of leaves, white oak; the second row, red oak; the third row, dogwood; the bottom row, sassafras. Each kind was taken from a single tree. How are the different kinds unlike, and how are the different leaves of the same kind unlike?

peach and elm trees; or they may be divided, as in white or red oaks, carrots, and cress. They may consist of many small leaves on one leafstalk; that is, the leaves may be compound,[1] as in clover, roses, and horse-chestnut or walnut trees. There are almost endless variations in the forms of leaves. Occasionally one may even find several leaf forms on the same plant, as in the sassafras tree.

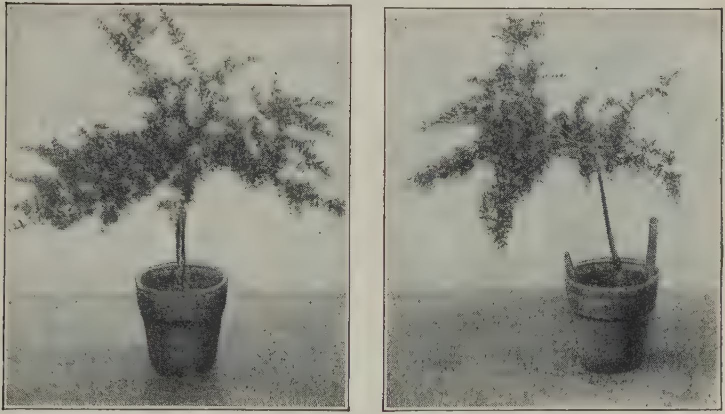

FIG. 206. A PLANT WHOSE LEAVES AND BRANCHES HAVE REACHED FOR THE LIGHT

At the left the plant is seen as it faces the window; at the right the same plant is turned one fourth way round. Can you explain the difference in the two pictures?

Project. To make a classroom collection of kinds of leaves. Make a collection, to be shown later, of the kinds of leaf forms you can collect from plants you know, or from plants the names of which you can learn by asking parents, neighbors, and teachers. Construct a wooden box with a glass cover in which the leaves may be kept for class use.

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[1] *Compound* (kom′pound): made up of several parts.

Experiment 45. How are leaves arranged on stems to secure good lighting? Examine such plants as sunflowers, beans, squash or pumpkin vines, dandelions, lilac twigs, and potted house plants, and write a description of the arrangement of leaves on stems to secure good lighting. Are all the leaves equally well lighted (Fig. 206)? Are any in shade throughout the whole day? Is there evidence that the leaves have grown into positions that will give them all good light? Will house plants change the position of their leaves when the pots are turned halfway round? Try this.

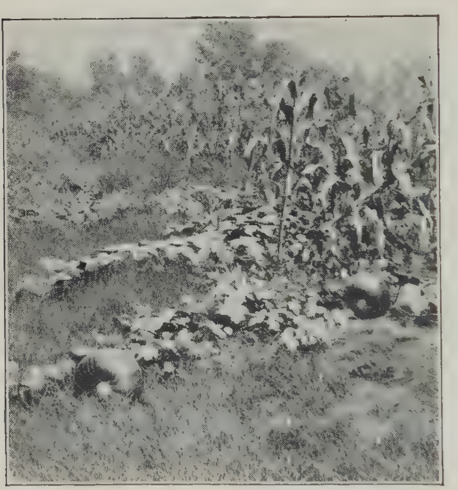

FIG. 207. STEMS OF DIFFERENT HABITS

The pumpkin stem grows on the ground. Do such stems ever climb on fences or trees?

242. †How stems behave. Stems and branches serve a twofold purpose: (1) to hold the leaves up in the air, where they can do their work; (2) to carry water and other food material up to the leaves and to carry manufactured foods down to other parts of the stem and to the roots. In trees most of the woody[1] part consists of the heavy cell walls of old cells in which the protoplasm is no longer living. These old cell walls are useful for support to the plant even though they are not alive, and a hollow tree whose central wood has decayed will still live and work if it is strong enough to support its load.

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[1] *Woody:* of the nature of wood; like wood.

Some stems have the habit of running along on the ground or of climbing on fences, houses, or stouter plants. Such stems as those of the pumpkin and watermelon, the trumpet creeper, the woodbine, and the morning glory, peas, beans, and grapes have borrowed their support from the earth or from structures that rise into the air. Wild grapevines have been known to grow over a hundred feet high on forest trees; trumpet creeper and woodbine have climbed to the roofs of two-story houses; pumpkin vines have been known to run more than a hundred feet on farm fences (Fig. 207).

Other stems grow underground and send up long leaf-stalks upon which large leaves expand, do their work, then die, leaving the stem well protected in its buried position in the soil. Such stem habits are seen in many kinds of ferns, in the May-apple plant, and many grasses.

243. *Storage of food in stems and roots. The common potato is a special kind of stem. The "eyes" of the potato are buds from which a new growth of stem, leaf, and root develops when the bud is planted. The leaves of the potato manufacture carbohydrates in large amounts. These are transported into the underground parts of the stem, are changed to starch, and are left there. The food stored in the potato is the plant's surplus supply.

*Sweet potatoes, turnips, radishes, beets, carrots, and parsnips are roots stored with food which the plant has been making and is holding till this food may be used in further growth or in making seeds. When a radish has produced seed, you find that the root is no longer good to eat. Most plants which store food in the roots do not produce seeds until the second year.

244. *Plants for clothing; fibers. As the cotton seed matures, the seed coat is covered by a mass of strong white threads, or fibers (Fig. 208). This is the material from which cotton is made. Many important industries, industries upon which hundreds of thousands of people depend, have developed because of the cotton fiber. Any disease that affects the cotton plant is of world-wide importance because the whole world uses cotton in one way or another. The nickname "King Cotton" for this plant is not an ill-fitting name. No other plants are quite equal in impor-

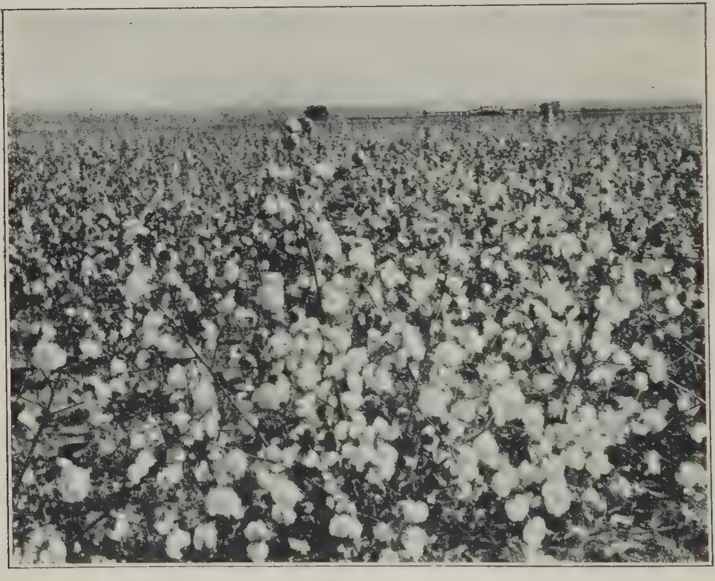


FIG. 208. A COTTON FIELD NEAR EL PASO, TEXAS

The long fiber which forms upon the cotton seed has become the basis of some of the most important industries in the world. The oil from the seed is used in many ways. How many articles can you name which are made from this plant?

tance to cotton, corn, and wheat. Cotton has more to do with clothing the world than has any other living thing. Besides clothing, we make it into cord and cloth for all sorts of uses, we use it as absorbent cotton, we make it into explosives and celluloid, and we get oil out of the seeds. The invention of machines for handling cotton, such as the cotton gin and the spinning jenny, has marked highly important stages in the progress of mankind.

We do not depend on linen for clothing so much as our ancestors did, but it is still important. The flax stem has very strong and fine woody fibers, and if the flax is grown in such ways that the plants crowd one another for light the fibers are long and smooth. We separate these from the rest of the stem and make them into cloth, thread, or twine. This material is called linen; when properly prepared it is of the finest quality for personal and household uses. Linen goods carry colors very well, and wear a long time if properly cared for. Furthermore, the use of linen in making fine articles for the household has long been a custom of our race. Good linen used to be an evidence of good social standing. It is not likely that people will soon stop caring for it.

245. Plants for pulp and print. Men and other animals make many uses of lint and pulp from plants (Fig. 209). The first books in Europe were written on sheets of coarse paper made by pasting together thin strips of the pith of a swamp plant. The Chinese found that paper could be made by matting together vegetable fibers; and by the time that this Chinese invention was brought to Europe the fiber of linen rags was being used. It was after this time that printing was invented. The first printing was slowly done, and often had some colored letters painted in with a small brush. The binding (that is, putting the leaves of paper together into a solid book) was also slowly and carefully done. The outside was at first always covered with leather, often with hard white leather. Very little machinery had then been invented for use in printing and binding. Such books were so few and so expensive that only very wealthy people could buy them.

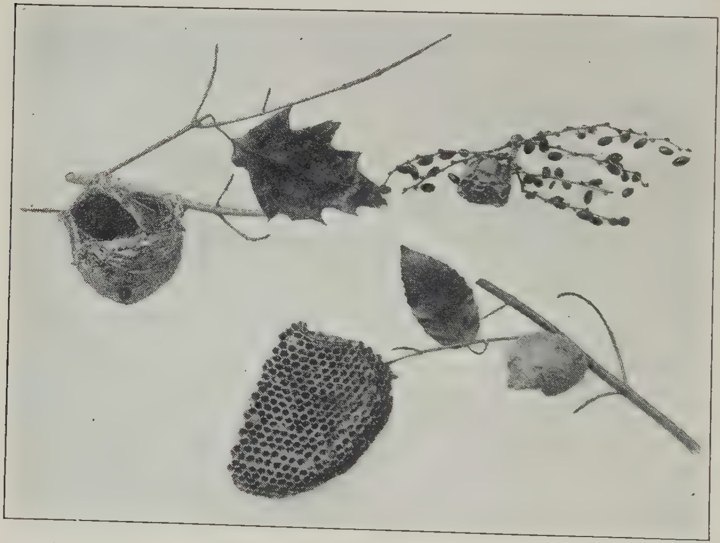
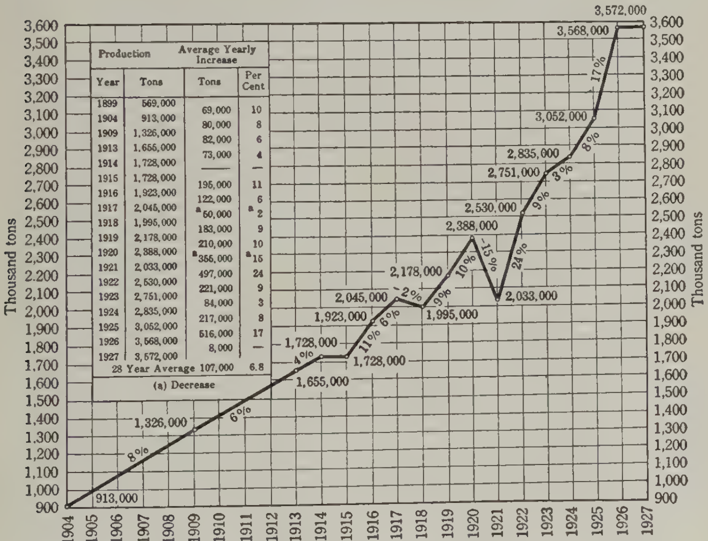


FIG. 209. PLANT FIBERS USED IN MAKING ANIMALS' NESTS

A vireo's nest made partly from grass and strings and covered with pulp or lint from sticks, boards, and possibly wasps' nests; two nests of a black wasp made from lint (one nest was fastened to a barberry plant and one beneath the roof of a house); a small nest of a hornet made from lint and fastened to the branch of a tree

Special Reports. From reference books prepare a report on the early history of paper and bookmaking. Visit a collection of old books, and describe a few of the oldest volumes.

†When books and newspapers began to be common factors in everyone's life, as they are today, there were great changes in the needs for paper and for binding materials. Cotton cloth prepared in several ways has become the common material for binding books. The best quality of paper, used chiefly in personal correspondence and in making special books, is made from linen cloth, usually old. Such paper is expensive; most books and the newspapers are printed on paper made from wood pulp. The stems of soft-wooded trees, such as spruce and cotton-



Production		Average Yearly Increase	
Year	Tons	Tons	Per Cent
1899	569,000		
1904	913,000	69,000	10
1909	1,326,000	80,000	8
1913	1,655,000	82,000	6
1914	1,728,000	73,000	4
1915	1,728,000	——	—
1916	1,923,000	195,000	11
1917	2,045,000	122,000	6
1918	1,995,000	ᵃ50,000	ᵃ2
1919	2,178,000	183,000	9
1920	2,388,000	210,000	10
1921	2,033,000	ᵃ355,000	ᵃ15
1922	2,530,000	497,000	24
1923	2,751,000	221,000	9
1924	2,835,000	84,000	3
1925	3,052,000	217,000	8
1926	3,568,000	516,000	17
1927	3,572,000	8,000	—
28 Year Average		107,000	6.8

(a) Decrease

FIG. 210. THE INCREASING USE OF WOOD PULP

Note that the table at the left gives the values which are shown on the graph. Note how the graph goes downward between 1917 and 1918, indicating that 50,000 tons less of wood pulp were used in 1918 than in 1917. The graph also goes downward from 1920 to 1921. Can you determine from the graph how much less pulp was used in 1921 than in 1920?

wood, are ground and treated with chemicals until the whole mass of woody tissue is made into a thick paste known as pulp. This can then be made into sheets of the thickness desired, wound into rolls, and shipped to the printing presses. In large cities it is not uncommon to see trucks on their way from railway stations to printing plants, carrying six or eight rolls of paper each weighing half a ton or more.

†Smaller quantities of paper, especially brown paper, are made from Manila hemp, straw, wild grasses, cornstalks, and other materials. In recent years small amounts of newsprint paper have been made from cornstalks and from other plants, such as wild grasses, but these sources, though of promise for the future, have not yet provided much of the total pulp and paper supply.

246. Amount of pulp used in printing news. The amount of pulp and paper required to carry on the book and newspaper business of the country is enormous. Fig. 210 shows not only the total amounts but the growth in use during recent years. The following record of a single day's issue of one large daily newspaper indicates the demands made upon plant life to keep up with our printing industries:

RECORDS OF ONE DAY'S ISSUE OF A NEW YORK NEWSPAPER

Number of pages in one day's issue	240 pages
Amount of reading matter	800 columns
Amount of advertising matter	764 columns
Extent of the paper if the sheets were placed edge to edge	32,056 miles
Weight of each completed paper	4.5 pounds
Paper used, each roll weighing about a half ton	1200 rolls
Amount of ink used	17,000 pounds
Capacity of each printing press per hour for a paper of thirty-two pages	36,000 papers
Number of modern presses used on this paper	9 presses
Time required for nine presses to print the whole issue .	about 27 hours

When we recall that not only the pulp for newspapers comes from our forests but that the ink itself is made in part from plant products, we can gain some notion of the task that plant life has before it if it keeps up the supply for our modern life.

> *Special Report.* Discuss the source and preparation of paper for the needs of a city newspaper in your vicinity.

247. Sources of materials for special uses. It is not possible even to list all the materials in daily use which come from plants. A few will suggest the whole array, and studies of local plant industries should add information.

†*Rubber* found little use until the last half of the nineteenth century. Its greatest use now is in the manufacture of automobile tires. Crude rubber is made from certain juices of many plants which grow in or near the tropics. In one method of producing rubber the bark of the tree is cut through. As the white juice flows out it is collected and put into a tank in a very warm room. The juice is then allowed to flow from the tank to a whirling disk, which throws off the juice by centrifugal force (see page 108). The high temperature evaporates the water, allowing the rubber to fall to the floor as a white powder. The rubber is then ready to be made into various products.

The increasing uses of rubber have led the scientists to look for new sources. They have made extensive experiments in growing a wild Mexican plant from the dried trunk of which rubber can be extracted, and have improved the plant so that it now contains more rubber than its wild ancestors. Extensive rubber plantations are already found in California. Further experiments with this plant are being made in the hope of producing offspring that will grow farther north and in regions where there is little water.

† Rubber is useful because it can be stretched and compressed and will shed water. After rubber has been in use for a long time or has been exposed for a long time to sunshine, to changes in temperature, and to oil and other substances it may lose its useful qualities.

How many uses of rubber can you list?

Tanning is a process which has been known since ancient times. Until recently the bark from oak and hemlock trees was used in preparing the skins of animals for men's uses. The skins and bark were placed in immense tanks and covered with water. A special chemical substance in the bark called tannin was dissolved by the water, and the solution helped certain bacteria to grow. As a result of their growth the skins were softened so that the hair could be removed. The skin itself could thus be cleaned and, by rubbing and oiling, could be made into condition for further use. In recent times a large part of the tanning is done by chemical processes which do not use the bark of trees or the old-fashioned tanning tanks.

Flavoring extracts are made either from plants or by chemical processes. Vanilla is made from the pods of a tropical climbing plant, the vanilla plant. Coffee, used both as a drink and as a flavor, is made from the seeds of a tropical shrub, the coffee plant. Wintergreen flavor is made from the leaves of the wintergreen plant, a creeping plant common in north-temperate woods.

Medicine, dyeing extracts, and *oils* are prepared from many kinds of plants.

† *Perfumes* as first used by men were substances obtained from a few animals, such as the musk deer, the civet, and the beaver. But thousands of years ago men learned to make more numerous and more delicate

perfumes from plants. At the present time most perfumes are obtained by distilling (see page 59) stems, leaves, flowers, and other parts of plants and then dissolving (usually in alcohol) the fragrant substances that are distilled out. Some of the most delicate ones are made by the older plan of laying flowers on or near a plate covered with fresh fat till the fat has taken the perfume of the flower; afterwards the perfume can be taken out of the fat by alcohol. But more and more kinds of perfume are being made by synthesis (see page 54) out of coal tar and other chemical materials.

248. *Plants with no chlorophyll. A plant which does not have its own chlorophyll (see page 356) — that is, a plant that is not green — must get its carbohydrate food from green plants which do have chlorophyll. Absence of chlorophyll means dependency.[1]

*When a loaf of bread is left in a warm moist place for a while, mold appears upon it (Fig. 211). The mold is a threadlike plant which grows through the bread and absorbs its food directly from the bread. After it has grown for a time, some of the threadlike branches grow upward and produce rounded black tips. Inside these tips are many very small cells, or *spores*. When set free by the breaking of the walls inside which they were formed, the spores cause the odor which is noted when bread has mold growing on it. Each spore is able when it comes into favorable conditions to grow and produce a mold plant like the one that formed it. These spores are very light, and so many are formed that they are distributed almost everywhere. They have been found as high as two miles by aviators, who caught them on moist or sticky plates of glass. The spores of bread mold and of many other kinds of molds are so abundant that molds develop almost wherever favorable food material and favorable temperature and moisture exist. Most kinds of food will become moldy[1] if they are left in an exposed and warm place. Leather clothing, such as shoes and gloves, may become moldy, but the mold on bread and the mold on shoes are not of the same kind.

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[1] *Dependency* (de pen′den sy): need of support; not being able to live or act entirely alone. *Dependent* (de pen′dent): unable to get along without help.

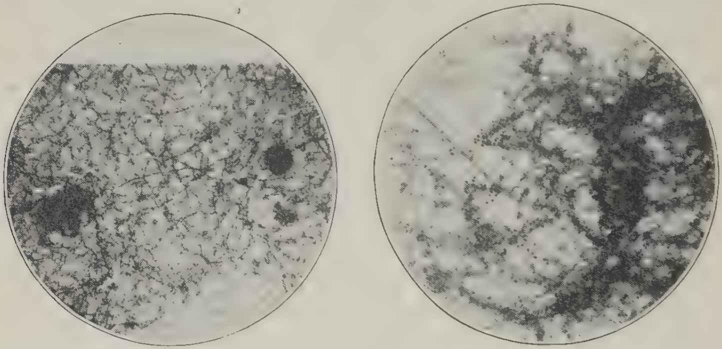

FIG. 211. MOLD PLANTS GREATLY ENLARGED

That at the left is mold grown upon water and is magnified seventy-six times; that at the right is bread mold and is magnified three hundred seventy times, and shows not only the threadlike mold plants but the black tips which contain the spores. (Photomicrograph by A. Iorio)

There are many kinds of molds, just as there are many kinds of trees or of insects. They are alike, however, in that they start from spores, grow on food as do other fungi,[2] and, as they grow, reduce the food to simpler elements and compounds (see page 51).

Experiment 46. What occurs when mold grows in breads? Place in the bottom of a glass dish a piece of slightly moist white bread which has lain on an outside window sill for ten minutes. Arrange a second piece of bread in the same way and sprinkle on it some dust from the floor. Keep each dish covered with a fruit jar or a piece of flat glass. If mold develops, note and describe its appearance on each of three following days. Does water appear in the dish? What happens to the bread? Explain. Can you devise a test to find whether the mold produces carbon dioxide?

---

[1] *Moldy:* full of mold; like mold.

[2] *Fungi* (fun′ji); singular, *fungus* (fung′gus): simple plants which have no chlorophyll.

249. *The yeasts and what they do. Yeasts are extremely small nongreen plants. Each plant consists of a single cell. A yeast cell produces a new plant by forming a bud from the old cell. Since a parent plant may have formed several buds, and some of these may in turn have formed buds, it may be that a whole group, or colony, of plants are found together (Fig. 212). Each plant cell, however, has its own problem of nutrition and reproduction.

*Yeasts get their food from sugar that is in solution. It may be sugar in moist bread dough, in grape juice, or in any other solution. In using the sugar for their own needs the yeasts produce a chemical change in it, breaking it up into carbon dioxide and alcohol. The carbon dioxide gas expands and causes the bread to rise. This makes the pores in the bread. Careful working of the dough helps to distribute the yeast plants, thus helping to insure more uniform action on the sugar. This helps to produce more gases and lighter bread. Baking vaporizes the alcohol out of the bread into the air. The action of yeast on sugar is called fermentation.[1] Fermentation is also caused by some of the bacteria and by some other fungi.

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[1] *Fermentation* (fur′men ta′shun): the production of alcohol and carbon dioxide by action of yeast on sugar.

†It was in connection with a study of yeasts in the brewing industry that Louis Pasteur, one of the world's greatest scientists, discovered how to separate different kinds of yeasts from one another. He also discovered that in fermentation different yeasts produce different results. Looking through his microscope Pasteur picked out a single

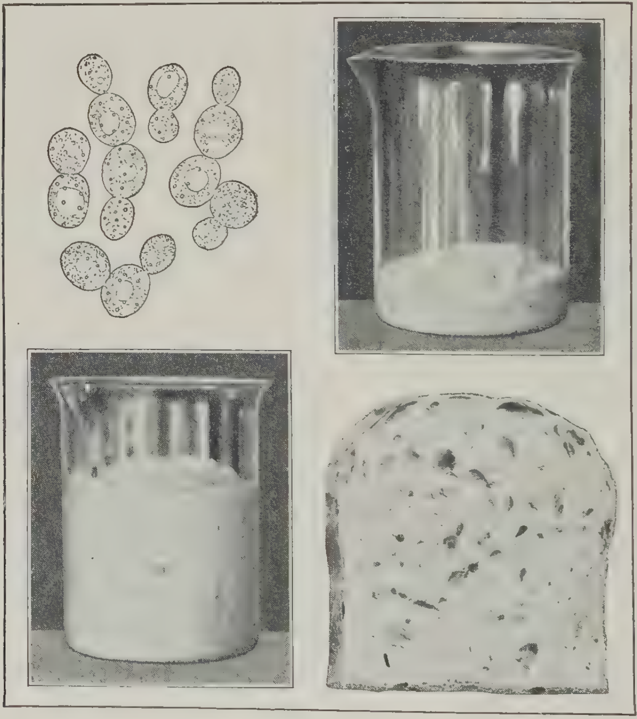

FIG. 212. YEAST PLANTS

At upper left, yeast plants much enlarged. New yeast plants are being formed by buds from the old ones. At upper right, dough in which yeast has just been mixed. At lower left, the same dough after standing a few hours. At lower right, the same dough made into a loaf of bread yeast plant and put it in a solution in which there was no other living thing. This plant and its rapidly increasing offspring were all of one kind. The results of their growth in the solution could be studied. By such study of both yeasts and bacteria it was possible, finally, to provide the kinds of yeasts or bacteria necessary to produce the desired alcohol, wine, or beer. Until that time it had not been known that such exceedingly small living things could be grown alone or that each produces its own particular results.

Class Report. Prepare a class discussion of the life, work, and influence of Louis Pasteur.

250. How mushrooms[1] **grow.** Most people think of a mushroom as being no more than the stalk and circular top such as is shown in Fig. 213; and we sometimes speak of things that take place quickly as "growing, like a mushroom, in a night."

Experiment 47. Where are the spores of mushrooms formed? Cut the top of any common mature mushroom from its stalk, and place this top right side up on a piece of smooth paper. By striking the top gently, or by leaving it for a few hours and then lifting it, collections of the dust which came from the slits or pores in the under side of the top may be found on the paper. In some kinds such collections make beautiful patterns on the paper.

*The dust consists of spores, each of which is a very small cell. The spores are produced on the ends of thread-like cells in the top. Sometimes they are formed on the sides of divisions of the top which hang downward, as in most common mushrooms; sometimes they are in pores within the top, as in the "shelf fungus" which grows from the sides of trees; sometimes they are entirely within the top, as in the common fungus called puffball.

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[1] It is not uncommon to speak of mushrooms and toadstools as being the same kinds of plants, except that mushrooms are good to eat and toadstools are not. In structure they are not different, therefore the name mushroom is used in speaking of the whole group.

*The spores are very small. Most kinds are a light powder that can be carried far by the wind. All kinds can adhere to the coats of animals and be carried by them. When they fall where there is the right food (different sorts grow on different kinds of animal or vegetable matter) and the right temperature and moisture, they germinate.[1] A small white thread is produced, and soon makes many branches. These threads push their way among the organic matter, using part of this matter for their nourishment. Since mushrooms have no chlorophyll, they have to find their food already organized.[2] In living upon and within their food supply they help to cause decay.

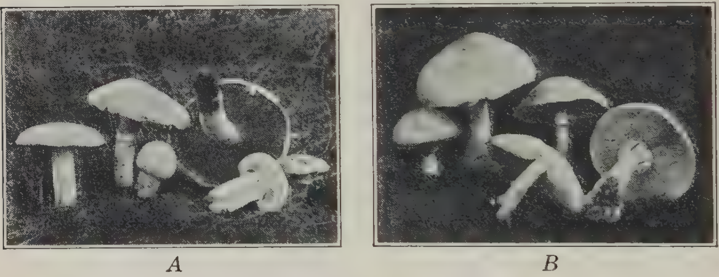

FIG. 213. TWO COMMON MUSHROOMS

Mushrooms help to break up the dead bodies of other plants and animals. *A*, one of the best of the edible forms, is called the meadow mushroom, or *Agaricus campestris*. *B* is known as *Lepiota*; some kinds of this form are good to eat and some are not. It is safe to eat only those that you have learned to know are good. (Photograph by C. S. Todd)

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[1] *Germinate* (jur'mi nate): begin to grow, as from a spore or a seed.

[2] *Organism* (or'gan izm): a body that has special parts for special work. *Organized* (or'gan ized) or *organic* (or gan'ic): made into an organism; in chemistry, made into compounds of carbon, such as living things are made of. *Disorganize:* break up so as to destroy the organized condition.

*In favorable weather, when the threads have grown enough, here and there a knot of the threads grows into a lump full of food, out of which (often very rapidly) grows what we call the mushroom. The main life of the plant is in the threads that have for a long time been gathering food; the quick-growing mushroom is nothing but the fruit. In some kinds the threads die after the fruit is borne; in other kinds the threads live on and bear their fruit in nearly the same place year after year.

251. *Ways of living. Since green plants can make their own food they are said to be *independent*; plants and animals that cannot make their food are said to be *dependent.* The molds, mushrooms, yeasts, and bacteria belong to a group of plants called *fungi*, a large group of plants which live at the expense of other things. Some live in, upon, or at the expense of other living things, and are known as *parasites* (see page 77); others live entirely upon dead and decaying things, and are known as *saprophytes*.[1] Most of the fungi are saprophytes. They are therefore very important as a means of breaking up dead bodies and making their material of use again. They greatly increase the fertility of farm, garden, and pasture soils. Some of the fungi are parasites; for example, the rust of wheat and oats, the smut of corn, wheat, oats, and rye, and the water mold which sometimes kills fish by growing in their gills.

252. *Bacteria are important plants. The large group of fungi called bacteria contains both saprophytes and parasites. Bacteria, like yeasts, are one-celled plants that secure their food from other things. There are many kinds of bacteria. Most kinds live in the soil or in water — wherever they can find organized food. Only a few kinds of bacteria cause human diseases. When they cause disease they are living in human bodies at our expense, and generally produce results harmful to us. In the main, bacteria are very useful in that they help to reduce dead organized bodies to simpler forms, releasing elements and compounds (see page 51) which may again be used in the food cycle. Bacteria are more fully discussed in Chapter XXIV.

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[1] *Saprophyte* (sap′ro fite): an organism that lives upon dead organic matter.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. Much of the food materials made by plants (by the turnip, for example) is stored in the roots.
2. Only plants which have chlorophyll can manufacture their own food.
3. Select from the following the word that does not belong with the rest: **mushroom yeast mold saprophyte clover bacteria fungi.**
4. Molds grow readily upon dry bread.
5. Yeasts act upon sugar to produce ____ and ____.
6. Spores of fungi have been found at a height of several miles above the ground.
7. Man is an independent organism.
8. A shelf fungus growing on a dead log is an example of a parasite.
9. Fungi are of great importance to man because they bring about the decay of dead bodies.
10. Most kinds of bacteria cause disease.

CHAPTER XXIII

THE LIFE HABITS OF SOME COMMON ANIMALS

Some Questions this Chapter Answers

What kinds of animals may be kept as pets? What is the home of a wild animal? What is meant by a "balance between living things"? How can a balanced aquarium be made? Do animals and plants produce more offspring than can live? How many animals must die each day to provide the food needed for a nestful of young birds? How may birds be of help to the farmer? What birds are useful and what ones are harmful? When and where do birds migrate? What important insect problems have been introduced within recent years? How should these problems be met? How may bees be kept for profit? How are silkworms grown for the production of silk? How may wild animal life be properly conserved? What is meant by "inheritance of parental characteristics"?

253. †Keeping animals for pleasure and profit. A farm without tame animals of some kind is hardly to be found. In the earliest history of human civilization there are pictures of animals as companions of men. Men seem always to have had an interest in animals, whether for work or for food or for pleasure. Even in the crowded city today animals are kept as companions (Fig. 214). Dogs, cats, rabbits, birds, fish, toads, frogs, turtles, and bees are found in homes in every large city. Many books have been written about the care of animal pets. Records are made of the ancestors of individual animals of the most desired types. These records are kept with great care and are studied when one expects to buy an animal of the better type. Such records are now kept both of the animals used for work or for food and of city and farm pets.

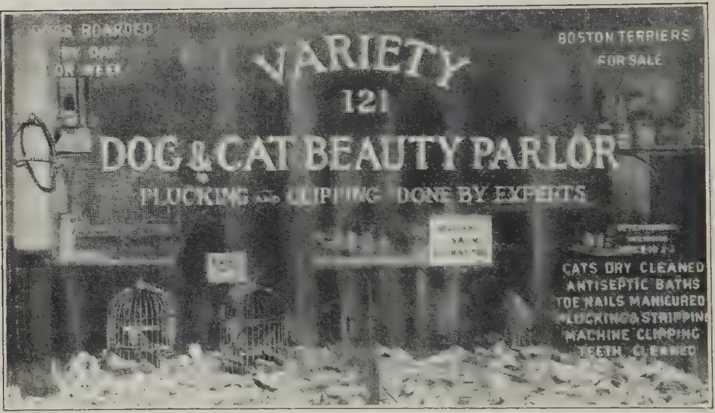

FIG. 214. CARING FOR ANIMAL PETS

Not only are pets cared for in and about people's homes, but their public care is being developed on a business basis. The above shop window is from a photograph taken in the center of a large city. How does your community take care of its animal pets?

†Not only are animals kept as companions, but men sometimes become almost as devoted to their favorite pets as to members of the family. Sometimes, however, animals are kept in cities with so poor care, so little open air, and so little thought of an animal's good health that the right to keep them must be questioned. People sometimes say they "think a great deal" of an animal when they do not think enough about it to take proper care of it.

We may have the legal right to own a pet and not have the human right to do so. Animals too have rights. It seems fair to insist that any person who arranges to keep a pet should feel it his duty to provide such conditions for it as will enable it to live comfortably.

254. The homes of animals. Most kinds of animals have homes. A family of young squirrels will often remain fairly near their hollow-tree home until they are fully grown. The young birds of a family often spend their first summer with their parents near the old nest. A pair of ground squirrels, raccoons, or foxes may use the same trees or dens as homes during their entire lives, their offspring living with them until grown, then hunting homes of their own. Ants, bees, wasps, and many other insects build homes to which they return regularly throughout all or the greater part of their lives, — indeed, until they leave for the purpose of constructing new homes.

Special Report. Find an ants' nest and discover the roads leading to and from it. Watch the ants as they move about, and find whether there is any system in their actions. How far from the home do they go? Can you find what work they are doing? Write a statement of what you learn about the ants' nest.

Special Report. Locate the home of some kind of wild beast or bird (for example, a nest of robins, blue jays, or wrens), study it for several days, and describe their home life; or describe that of tame mice, rats, or rabbits.

255. †A balance between living things. It is common to see an aquarium[1] (Fig. 215) in which fish, possibly other animals, and plants are living together. In such aquaria if the fish eat too much of the plants, the plants will disappear sooner or later; if the fish cannot get food enough, the fish will die. The same thing is true of other things living in an aquarium or vivarium.[1] Toads, snakes, snails, frogs, or crayfish, with several kinds of plants, may be grown in an aquarium or vivarium in the home or schoolroom if care is taken to keep a proper balance of life.

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[1] *Aquarium* (a kwa′ri um); plural, *aquaria* (a kwa′ri a): a specially made jar or tank, usually of glass, in which water plants and animals may be kept alive.

†Toad or frog tadpoles living in the water of aquaria produce some carbon dioxide which goes into the water.

FIG. 215. PLANTS AND ANIMALS MAY BE GROWN IN AQUARIA AND VIVARIA IN THE SCHOOLROOM AND HOME

The tadpoles must secure some oxygen. If plants such as water weed or the thousand-leaf are growing in the water, they will consume carbon dioxide and release surplus oxygen by photosynthesis (see page 351). If no other kinds of living things were in the aquarium, the tadpoles and plants might both do well. The tadpoles, however, need to eat organic matter such as is found in slime[2] on the sides of the glass and on the plants. If they have food enough they grow, and as they grow they need more food. As they grow they develop legs, their tails shrink away and disappear, and they change their way of moving about. The kind of food they need changes, since they now want insects to eat and not slime. Even if the plants should grow rapidly enough to keep up with the growth of the tadpoles, they could not provide proper food when the tadpoles become frogs or toads. Hence although there may be a balance of life at one time, there may not be at a later time. In most aquaria, therefore, it is necessary to give constant care to see that proper food and conditions are provided for each of the organisms in them. If more food is given the fish than they can eat, it decays and soon produces conditions harmful to both the fish and the plants. If the plants do not have some soil and proper light and temperature, they cannot live; if they are exposed to rapid eating by animals, they are all destroyed.

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[1] *Vivarium* (vi va′ri um): a place for keeping either land or water animals alive.

[2] *Slime*: wet, soft, slippery matter, sometimes made up of very simple plants.

It is possible, though difficult, to produce a closed aquarium in which there is a balance of life that may go on for years. In such a case there are just enough water-breathing animals such as fish or crayfish to provide carbon dioxide and organic matter for the plants and to use the surplus oxygen produced by the plants. There are just enough plants to produce the needed oxygen and to use the carbon dioxide and organic matter produced by the animals. This is called a balanced aquarium. In practice, however, most students will need to keep the aquarium balanced by their own rather constant care.

Special Report. Explore a pond or stream in your neighborhood. How many different water plants and animals can you find? Can you learn the names and habits of any of these?

Project. To make and maintain an aquarium. Can you make an aquarium in your classroom or home and keep it working effectively for two months or more? Secure a large glass vessel or tank a foot or more in each of its measurements. Place some pebbles and two or three inches of soil in the bottom. Place a stone or brick so that its upper surface comes within three or four inches of the top. Fill with tap or stream water to six or eight inches from the top. Secure a water weed or a thousand-leaf from a stream or from an aquarium-supply store and place it in the water. Place two small fish and a green frog in the water. Each day give the fish a small amount of fish food secured from the supply house. Give the frog a fly or any small piece of red meat. How can you feed the frog? Write a record of your success after two months.

Project. To show what work with animals your class is doing. Arrange a school exhibit with a description of all the animal pets kept by members of your class. Build suitable display cages for some of the pets and include these pets in the exhibit.

256. †How many animals? No one knows just how many animals there are in the world. In fact, new kinds of animals are still frequently discovered. It is supposed that many kinds of insects have not yet been made known to science. New kinds are found by almost every trained student who goes into the wilder regions of the earth.

†Not only are there many kinds of animals, but each kind would produce a large number of offspring if nothing prevented it. Thus, if a pair of robins should live for five years and should produce two nests of young each year, if each nest of young should consist of two pairs which would begin nesting in their second year as their parents did, and if none died, there would be 6250 robins in this five-year family.

A pair of house wrens may produce two nests of young each year and may have as many as eight or nine offspring in each nest. If one pair of wrens had begun nesting the summer before you started to school, and had had eight young in each nest, if the young had begun nesting their second year, if their offspring had been equally paired males and females, and if the first pair and all their offspring had lived until now, how many wrens would there be in this family at the present time?

†In 1869 the English sparrow was brought to the United States. It was brought here to help toward controlling caterpillars.[1] A statement printed in 1869 says: "John W. Bardsley of Germantown, Pennsylvania, who went to Europe several months ago, was commissioned by the city council to purchase 1000 English sparrows to be placed in the public squares of this city." The United States Department of Agriculture prints the statement that a single pair of these sparrows, if not limited in any way, would in ten years produce 275,716,983,689 sparrows. Although sparrows do not increase so rapidly as this, it is true that they have increased remarkably and have spread over the whole country.

†A female lobster may lay from 5000 to 10,000 eggs in one season. A female black bass may lay thousands of eggs in her few hours of egg-laying. A Cecropia moth brought into the laboratory laid 126 eggs in one afternoon. A prize White Leghorn hen laid 352 eggs in one year. Find out how many young any common animal will have in ten years. It would not be long, if there were nothing to stop them, before the animals of one kind would be crowding each other upon the whole earth.

---

[1] *Caterpillar* (kat′er pil′ler): the wormlike young of moths and butterflies.

257. †What a nestful of birds can eat. A nest of house wrens three quarters grown (Fig. 216) were brought food by their parents one hundred and ten times in four hours and thirty-seven minutes. Not all the kinds of food could be recognized while the feeding was being watched, but that which could be seen included one hundred and eleven insects and spiders. On the next day the nest was watched again, and the young birds were fed sixty-seven times in three hours and five minutes. Another nest of house wrens was fed seventy-one times in one hour, an unusually rapid rate of feeding.

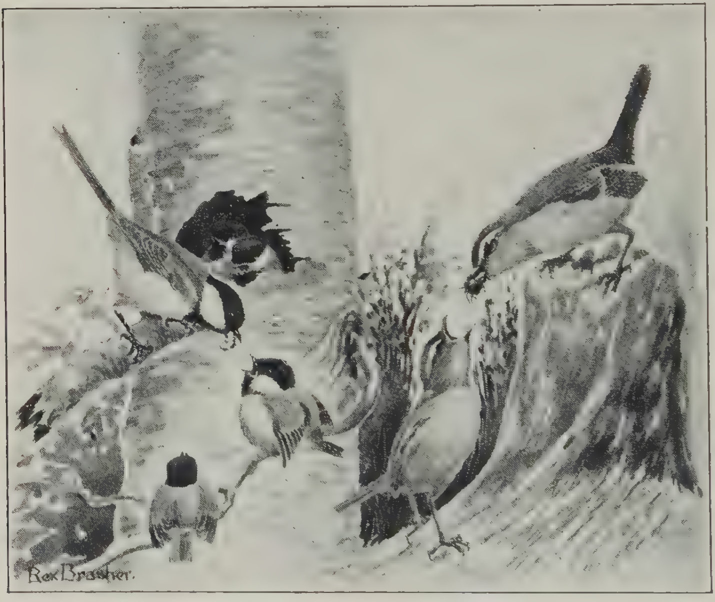
Rex Brasher.

FIG. 216. HOW MUCH DO YOUNG BIRDS EAT?

An old wren and a young one at the right; an old chicadee and four young ones at the left

†In feeding young chickadees (Fig. 216) the parent birds were observed to make six visits in thirteen minutes. The parent birds carried several small insects on each visit. On examination it was found that they were feeding their young with ants, plant lice, and spiders.

258. † Birds which help or harm. The amount and nature of the food eaten by adult birds has been extensively studied by scientists in the Biological[1] Survey[2] of the United States Department of Agriculture. This research has been of great value in proving what birds are useful and in what ways (Figs. 216 and 217). Some of the results obtained are given in the following summary:

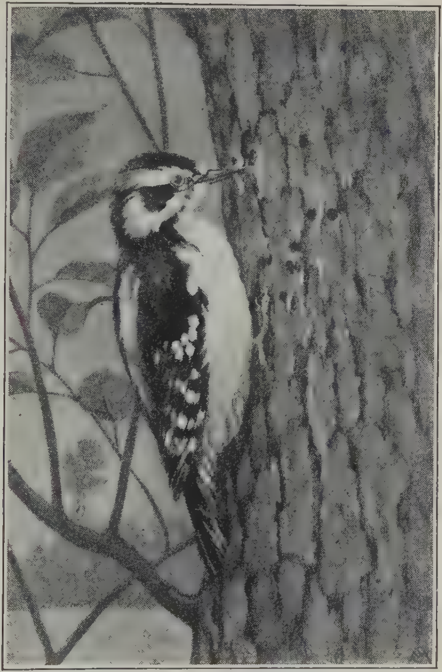

FIG. 217. WORKING FOR HIMSELF AND FOR US

A downy woodpecker digging from an oak tree the larvæ which destroy wood

One yellow-billed cuckoo, commonly called rain crow, ate 217 fall webworms, and another ate 250 tent caterpillars. Tent caterpillars eat the leaves of fruit trees, and in spring make tentlike homes where the branches come together. Webworms make a web all over a branch of a tree in the fall, and devour all the leaves inside the web.

---

[1] *Biology* (bi ol′o gy): the science which includes the study of all plants and animals. *Biological* (bi o loj′i kal): having to do with biology.

[2] *Survey* (sur′vay): an examination of all the parts of a thing to find out its condition, quantity, and so on.

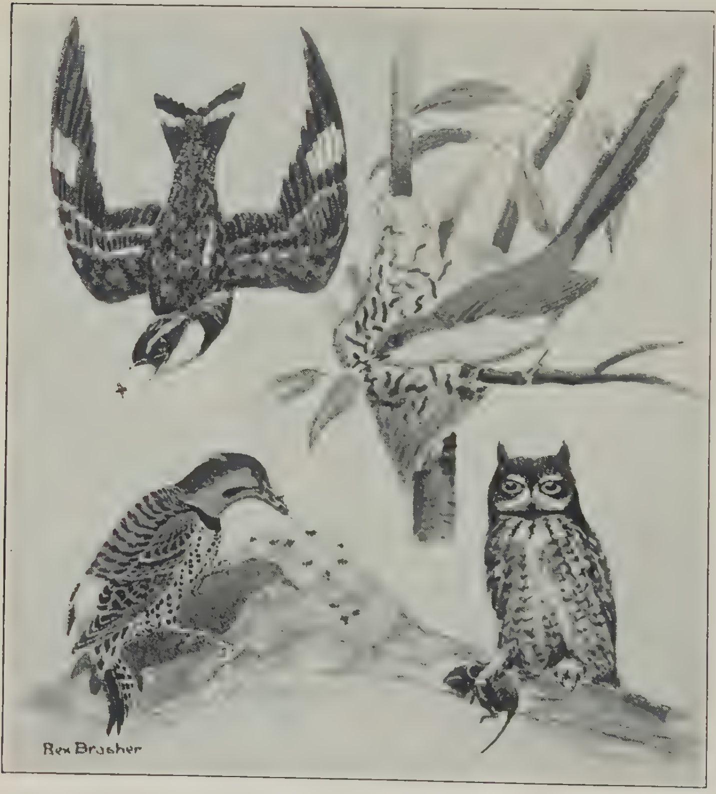

FIG. 218. FOUR VALUABLE BIRDS

Upper left, a nighthawk catching a mosquito; upper right, a yellow-billed cuckoo eating tent caterpillars; lower left, a flicker eating black ants; lower right, a screech owl with a mouse

One nighthawk ate 60 grasshoppers, another ate 500 mosquitoes, and a third ate over 1000 ants. A bobwhite, or quail, ate about 1700 weed seeds in one day.

Flickers are known to eat large numbers of black field ants (Fig. 218). These ants injure the roots of corn because of a most peculiar habit: they like to eat the sweetish fluid made by certain kinds of plant lice. The plant lice live on the sap which they suck from the tender roots of corn and grass. The ants dig dens in the soil down to the roots of the corn, then carry the plant lice down through these dens and put them on the corn roots. When the lice get plenty of sap they produce the sweet substance which the ants like. More flickers means fewer black field ants; fewer black field ants means fewer plant lice; fewer plant lice means less injury to corn; less injury to corn means better crops; better crops means more successful farms; more successful farms should mean more chances for farmers' children. We can see, then, how much depends upon the help of birds like the flicker.

*Such studies, made by many workers, show that only a few birds are harmful much of the time and that almost all are useful most of the time. It is hard to make a good case for the crow, the blue jay, and the cowbird (Fig. 219). Crows and blue jays destroy the eggs and young of other kinds of birds. Cowbirds, like a few other less common birds, lay their own eggs in the nests of other, smaller birds. Then when the cowbird young are hatched they greedily reach for all the food that is brought and soon are large and strong enough to push out of the home the young birds that belong there. In this case no favor is returned for the help received, but much harm. The crow, blue jay, and cowbird do good as well as harm, however, since they devour harmful insects.

259. †Where and when the birds go. Nearly all our common birds move southward[1] in the autumn and northward in the spring; that is, they migrate. People watch for the first birds in the spring and sometimes keep records of their return. Usually we do not note the autumn migration until we are suddenly aware that the birds are gone. In both the spring and the autumn we may see northern birds passing through the temperate zones, some making short stops to feed and possibly to rest. By careful listen-

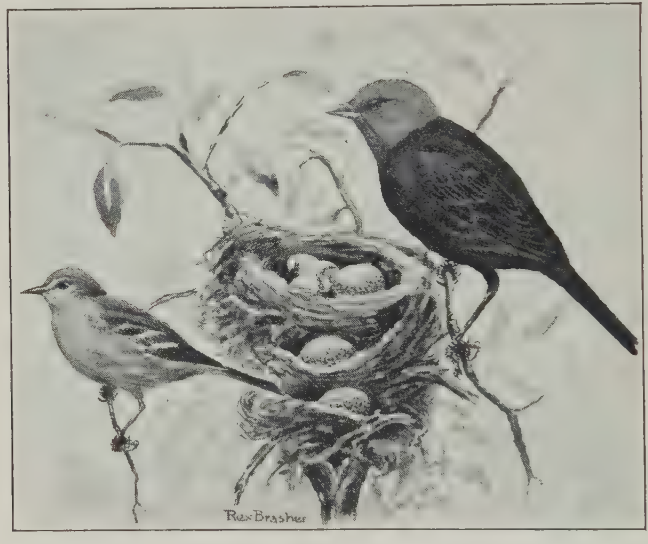

FIG. 219. STEALING A HOME

The cowbird (at right) does not build a nest, but lays its eggs in the nests of other, smaller birds. In this case the nest of the yellow warbler (at left) shows three tragedies. The first nest was used by the cowbird, and the warbler built a new nest upon the first, leaving the cowbird egg below. This occurrence was repeated. In the third nest are three warbler eggs and one cowbird egg ing at night in spring and again in autumn we may hear the flocks of various kinds as they speed on their long journeys.

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[1] *Ward* added to a word indicating a direction means "toward."

The golden plover (Fig. 220), a near relative of some of our common water birds, provides a striking illustration of a bird's round of travel and activity. Not many migrations are like this one, but each kind of migrating bird will provide a story of interest if its year-round travels and habits are learned. If (as is the common understanding) an animal's home is where it makes its nest and rears its offspring, the home of the golden plover is in the northernmost part of North America.

By looking at your map, as you will need to do while reading about this bird, you

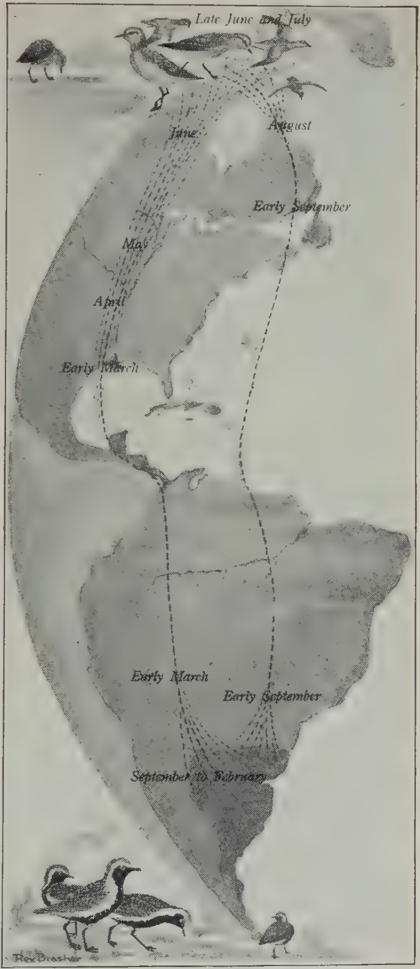

FIG. 220. MIGRATION OF THE GOLDEN PLOVER

Can you trace the journey from the nesting region in Canada and return?

will see large islands in the Arctic Ocean. You can find Kotzebue Sound in northwest Alaska, and Melville Island, Banks Island, Victoria Island, and Baffin Island far to the north and northwest of Hudson Bay. These are the nesting places of the golden plover. Arriving here at any time between the middle of June and the first days in July, the birds at once make their nests on the ground, using a few leaves or a little dead grass as the materials for the shallow nest. Here are laid four (occasionally five) yellowish-olive eggs, each about one and a quarter inches thick and about two inches long. In six weeks the eggs have hatched, the young birds have grown to full size, and their wings have been given trial and exercise. Then begins an interesting chapter in their story.

All the flocks of old and young birds begin to move southeastward, feeding on the abundant insect life as they go. The old birds go ahead, and the younger ones follow. Late in August the flocks have reached such southeastern shores as those of Newfoundland and Nova Scotia. They have eaten vast numbers of insects and are fat and strong. Then comes one of the wonders of animal life. The advance flock rises and starts for South America, followed for days by succeeding flocks of their own kind. In good weather the birds are thought to fly, without stopping, not less than three thousand miles. They land in two or three days, thin and tired, and ready to feed and rest in the plains of Argentina in South America. When storms are along the Atlantic coast many birds are blown to land; indeed, when there are no storms a few birds are sometimes found along the North Atlantic coast. Years ago in times of ocean storms thousands of these birds were killed by hunters from Long Island to Newfoundland; even today hunters search the coasts for any golden plover unfortunate enough to be driven to the shore within the range of their guns.

After feeding in Argentina for a few months the journey northward begins, a slow and long feeding trip over the plains of South America. By early spring the flocks are to the south of the great forests of South America. Being birds of swamp, shore, and plains, they rise again and fly northward over the forests. Early in March they arrive on the plains of Texas and Louisiana, again thin and tired from a long flight. Then they again move and feed slowly, working northward through the Mississippi Valley, devouring insects in great numbers. They eat grasshoppers, locusts, crickets, cutworms, wireworms, and other small animal life. They devour these insects in springtime, thus doing much good by killing off the parent insects of what might have been large families of destructive insects. This slowly advancing, insect-feeding army of golden plovers, spread wide over fertile plains, goes northward from March to June. It reaches its home, and the story begins once more.

260. *Problems some insects bring us. The Japanese beetle was first found in this country at Riverton, New Jersey, in 1915. It has spread rapidly and widely. By the end of 1928 it was in Connecticut, New York, Pennsylvania, New Jersey, Maryland, and Delaware. It will probably soon appear in other states. This insect belongs to the group known as beetles, and has the hard covering common to that group. It can endure many hardships without being killed. Its young live in the ground upon the roots of many kinds of plants. The adult, or full-grown, beetle can live on the stems, leaves, flowers, fruits, and seeds of many kinds of plants. This insect has a longer adult life than most insects, hence it can do more damage by its longer period of eating. It has a few known natural enemies, as some birds and certain flies and wasps, but these have not yet been able to stop its advance. The government has voted large sums of money to study this beetle, to find and encourage its enemies, and to establish quarantine[1] in the effort to prevent its extension.

> *Special Report.* Secure from the Division of Entomology[2] of the United States Department of Agriculture the latest bulletins[3] on the Japanese beetle, and prepare a class report showing what you think can be done about it and why.

†The European corn borer (Fig. 203, p. 363) is an insect recently introduced into the United States. In 1909 and 1910 it came as a most unwelcome guest in some broom corn which was shipped from Italy and Hungary into this country. The insect got started in three centers, from which it has been spreading rapidly. One center was near Boston. From this it spread over eastern Massachusetts into Rhode Island, Connecticut, New Hampshire, and Maine. Another was near Schenectady, New York, from which it spread over eastern New York into Vermont and Massachusetts. The third region was in Ontario. From this center the insect spread all round Lake Erie, round the western part of Lake Huron, and into New York, Pennsylvania, Ohio, Michigan, and neighboring regions.

*The damage done by the corn borer is very large. In Ontario alone over twelve thousand square miles of the corn crop was completely destroyed in one year. The United States government and the state governments have voted many millions of dollars to stop this damage. The European corn borer can live on at least two hundred and twenty-five different kinds of plants; so that when corn fails it for a time, it can change its preferred diet and eat something else until there is another supply of corn.

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[1] *Quarantine* (kwor′an tene): a law for keeping disease germs or small pests from being carried to places that do not yet have them.

[2] *Entomology* (en to mol′o gy): the study of insects.

[3] *Bulletin* (bul′e tin): a printed brief official summary of important facts.

Special Reports. Secure from the Division of Entomology of the United States Department of Agriculture the latest bulletins dealing with the European corn borer. Prepare a report or discussion on this topic for your class. What is your community doing and what can it do to help in this problem? Secure bulletins from the same source and prepare similar reports on any other destructive insects which may be important in your community, such as the Colorado potato beetle, the grape-root louse, the cotton-boll weevil, the San José scale and other scales, or the codling moth.

261. Bees and ants. Bees and ants have developed habits of home life almost beyond the belief of those who have not studied them. Ants, for example, have constructed extensive homes underground or in trees, with rooms for different uses, and with different ants assigned to the care of the different parts of the home. Ant families have their queen ant, whose duty is to lay eggs to provide future members of the colony; nurse ants, which care for the eggs and young ants; soldier ants, which guard the entrances or go out to fight enemies; workers, which go hunting for food and bring it for the common uses of all. In some ant communities, which store food in the form of sweet substances almost like honey, the food is fed to certain ants which hang from the roof of small rooms within the home. A storehouse ant swallows honey till its body is stretched into a round bag with a head and legs at one end. When the other ants need food they come for it and cause the storehouse ants to give up part of the food. Some ants even plant fungus spores upon cut leaves of plants, and in darkened rooms within the earth thus grow their own mold, or mushroom field. These are but a few of the things one may learn by a study of ants.

†Bees are of many kinds. The most familiar are bumblebees and honeybees. Both are useful and merit study and care. Bumblebees visit the flowers of field crops, and in so doing carry pollen from one flower to another, thus helping to distribute the pollen necessary in forming the seeds. In this way these bees are highly important factors in the crop of seed in clover fields.

†Honeybees have a community organization somewhat like that of ants. Their habit of gathering nectar from wild and cultivated flowers over a wide range of country is of great importance. A good hive of bees may store up fifty pounds or more of honey during a season, in addition to the amount required to care for the needs of the bees themselves. One who studies bees and cares for them properly is likely to receive a good return for his efforts.

262. *Insects and education. The few illustrations here given of harmful and useful insects will indicate the importance of insect study. We see its importance better when we realize that there are more kinds of insects than of all other kinds of animal life combined; and still better when we realize that, with the almost unlimited possibilities of reproduction among insects and with the wide range of their food supply, we do not know how to keep some kinds (Figs. 221 and 222) from destroying the things upon which we human beings depend. They eat our food and our clothes, they live in our kitchens and our bedrooms, they attack our flowering plants and our books (not omitting those written about insects), and a few kinds, if

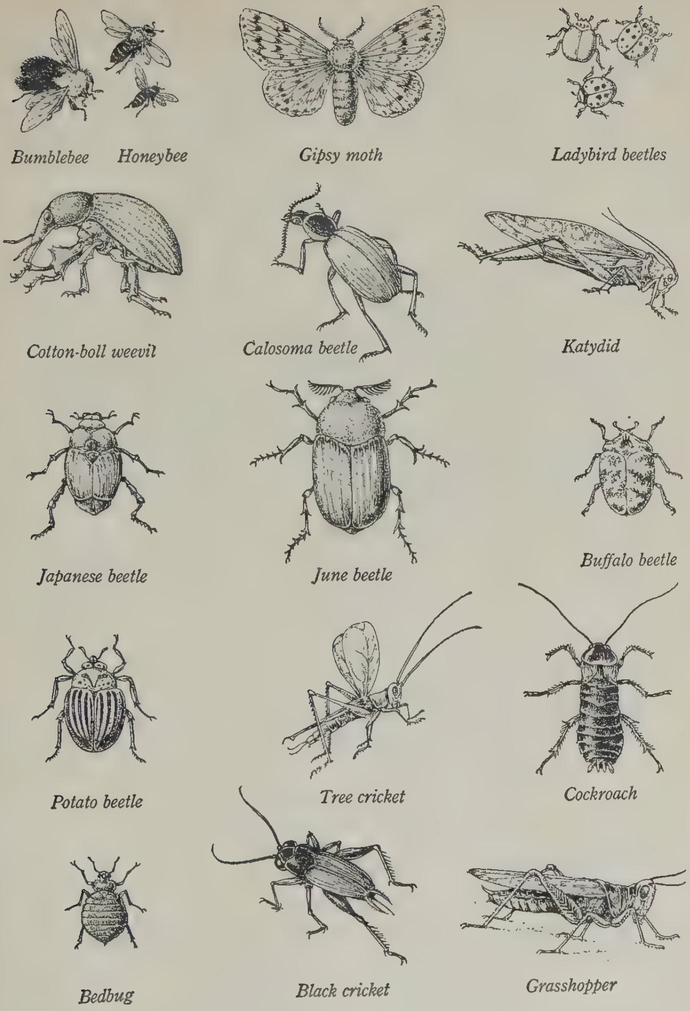
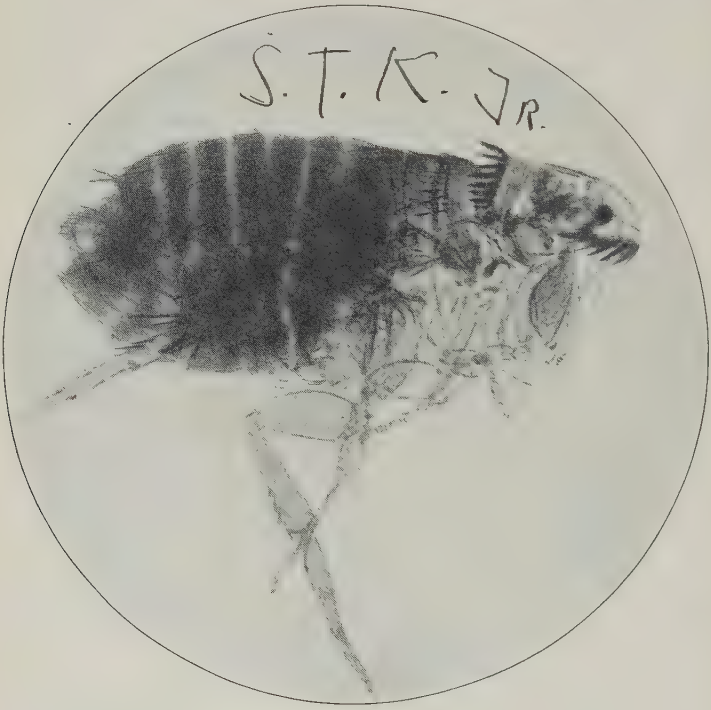


FIG. 221. SOME COMMON INSECTS

Information can be gained about the life and habits of these insects either in this book, in library books, or in bulletins from the state and national agricultural experiment stations they are not kept away, will devour the poisons put in museum exhibits to protect the exhibits against insects. Insects give man much to learn about and much work to do in using this knowledge in solving insect problems.



S.T.K. Jr.

FIG. 222. AN ENLARGED VIEW OF A CAT FLEA

This picture was taken through a microscope which made the flea look sixty times as large as it really is. (Photograph by A. Iorio)

If men do not learn how to meet these and other problems in science they will have great losses and disappointments, and possibly may be hungry as the result of failure to learn. True learning includes gaining new knowledge as well as coming to know what others have recorded. Science always has problems at hand to be solved and still more problems "just round the corner," waiting to come into view when the others are solved.

†Silkworms have been making silk for a very long time, and men have learned a little about the growth and care of the moths, eggs, worms, and cocoons, and about the silk from the cocoons. Honeybees have been making honey since the earliest history of man, and probably before his history began to be recorded. We have learned a little about bees and about their proper care and the care of their product. Other useful insects, as well as the harmful ones, are important as objects of study.

263. *Conservation of wild animals. The first settlers found this country full of wild animals, and suffered much damage from them. The bear, the panther, the wolf, the fox, the mink, the hawk, would kill the farmer's chickens or pigs, sometimes a calf or a colt. The deer and the rabbit would eat his crops. On the other hand, he needed the animals' flesh for food and their fur for clothing. Thus he had two reasons for killing the wild animals of which the wood and plains were full: (1) he must protect himself against them and (2) he must use them as supplies for his needs. As the country was made into farms, and towns grew up, there was less danger from harmful animals and less need to hunt animals for food; but hunting for pleasure or because of the desire to kill has gone on until it has become needless and cruel destruction of wild life. Along with this practice there has developed an added danger to the animals. As the country became settled the kinds of homes in which many of the wild animals had produced their young were slowly destroyed. The buffalo could not roam over the plains when the plains were fenced and plowed. The diminishing forests no longer provided abundant nesting and hiding places for their thousands of living things.

*The United States government and most of the state governments now have laws known as game laws to protect certain kinds of birds and other animals; for example, one cannot kill deer, wild duck, quail, or many other animals except during certain short periods, if at all. There are officers whose duty it is to see that people obey these laws.

*Great areas of national and state parks, or forest preserves, have been established, partly to help toward protecting wild animal life. These parks are the people's playgrounds, and are places for pleasure and for learning about nature. They are proving of great importance in saving and increasing wild life of many kinds which would otherwise soon disappear.

Special Reports. Secure from your state game commission, or state secretary, copies of your state laws regarding protection of birds and other wild animals, and prepare a class report on this topic. Other pupils may prepare a similar report from materials secured from the United States Department of Agriculture.

Project. To find out what wild animals, such as birds, squirrels, raccoons, opossums, gophers, or foxes, make their homes near your home. Observe these animals to see whether you can find out the answers to these and other questions about them: Exactly what kinds of foods do they eat and feed their young? How many young do they have? Do they teach their young how to find food, to avoid danger, and otherwise to get along better in their environment? Make a birdhouse to fit the needs of some particular kind of bird (Fig. 223).

264. *Range in kinds of animals. Animal life, or the animal kingdom as it is sometimes called, includes animals with the greatest range in structure and in habit. There are one-celled animals, like the amœba,[1] so small that they cannot be seen without being greatly magnified. There are large animals, like the elephants. There are intelligent apes; there are men. Many of these have different, highly organized structures which enable them to do their different kinds of work.

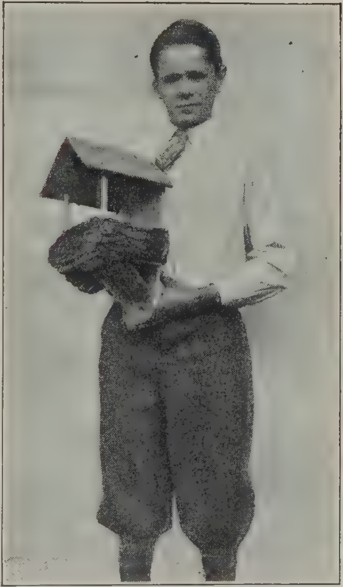


FIG. 223. A HOMEMADE BIRDBOX FOR THE YARD OR GARDEN

This eighth-grade boy built this nesting place for robins. Can you make a similar one or one suitable for another kind of bird?[2]

*The difference in size between the largest and the smallest animals is not so important as the difference in structures and habits. Man and the furry or the hairy four-footed animals are known as mammals; that is, they produce milk to feed their young. Mammals, birds, reptiles (such as snakes, turtles, and alligators), amphibians (such as frogs), and fishes are classed together as vertebrates, which means that they have a backbone, or vertebræ.

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[1] *Amœba* (a me′ba): an exceedingly small one-celled jelly-like animal that lives in water and upon very moist earth.

[2] A project suggested by Mr. Marshall L. Byrn.

Vertebrates have a body built around jointed bones, which make it possible for a large body to stand up and move strongly; and mammals and birds, by feeding their young, are able to teach their young how to live, and thus give them an advantage over the many animals whose young never know a parent. Crabs, spiders, insects, snails, clams, starfish, worms, and sponges are called invertebrates, meaning that they have no backbone. Some of these, like crabs, lobsters, and insects, have a jointed hard shell which gives them some of the advantages that vertebrates get from bones.

265. *Simple and complex animals. The simplest animals can get their food material and can produce offspring. That is what the higher animals do. But the one-celled animals and the one-celled plants do these two necessary things in very simple ways: they absorb their food through any part of the cell wall, and when they produce new animals or plants each divides into two new ones. It is known that the oldest living things on the earth were like these simple one-celled forms. As time went on the animal bodies and the plants as well came to have many cells. Some of these cells (see page 355) did part of the work, and other cells did other work, which means that animals slowly became more complex and also more and more able to get food and to produce their offspring. This increase in complex nature from simplest to highest animals is one of the most interesting facts about animal life.

*Another interesting and important fact of animal life is that offspring are both like their parents and different from them. An animal gets its structure, form, and appearance from its ancestors; that is, it inherits[1] a likeness to its parents or other ancestors. The process by which offspring inherit a likeness to their ancestors is called heredity.[1] Heredity causes a child's eyes and hair usually to have the same color as those of one or both of his parents or of one of his grandfathers or grandmothers. Sometimes, however, a child may have red hair when his only known red-haired ancestor lived several generations before. Occasionally there appears a characteristic that no known ancestor had. Persons may inherit characteristics that they would like not to have, such as defective eyes or weak lungs, or less intelligence than they need. One cannot change what he has inherited, but he can make the most of his good qualities. One who has inherited many good characteristics in body or ability can make them of little use or can make them of constantly increasing use.

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[1] *Inherit* (in her'it): to be born with a characteristic or quality which a parent or more distant ancestor had.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. Select from the following list of birds the one that is probably of least value: **robin** **plover** **lark** **crow** **owl** **hawk** **flicker.**
2. A bird that does not hatch its own young is the ____.
3. Of the following the insect that causes the least destruction is the **bee** **ant** **corn borer** **cotton-boll weevil** **cockroach.**
4. The most numerous kind of animal is **the bird** **man** **the reptile** **the insect** **the mammal.**
5. Unless men learn how to keep down the numbers of certain kinds of insects, human beings are liable to starve.
6. Insects are for the most part well suited to their environments.

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[1] *Heredity* (he red'i ty): the possession of characteristics and qualities inherited from ancestors.

7. Select from this list of animals the one that is not a vertebrate: snake cat man bee dog sheep chicken robin.
8. Select from this list of animals the one that is not a mammal: sheep cow man chicken monkey cat dog.
9. It is necessary to make and enforce laws for the protection of wild animals of many kinds.

SCIENTIFIC PUZZLES AND GAMES

As Jane and Alice were walking to school one fall morning, Alice suddenly cried out: "Look at that horrid spider! Step on it!"

"Oh, no. Don't hurt it," said Jane, holding out her hand for the big golden-yellow spider to crawl into it.

"Look out!" cried Alice; "it will bite you! You wouldn't get me to touch it — not for anything!"

"It won't hurt you. I'm not a bit afraid of it. See what a beauty this fellow is. And as for biting, there are very few poisonous spiders, only tarantulas, which don't live here. Here, you hold him and see how pretty he is."

"Ugh, no!" said Alice, shrinking back. But when she saw Jane laughing at her she finally held out her hand timidly. The first two times Jane put the spider on her hand, Alice dropped it, but the third time she kept it and soon lost her fear of it.

"I'll tell you," said Jane, "let's take it to school and look at it under the microscope. You've no idea how funny and interesting spiders' heads and mouths are."

The surprising fact was that when, a few minutes later, a crowd of boys and girls gathered round Alice and Jane to look at the spider, Alice's enthusiasm was as great as Jane's. She had entirely forgotten that a short time before she had called her "yellow beauty" horrid.

Which of the scientific attitudes (pp. 8–10) are illustrated by this story?

UNIT X. THE NATURE AND NEEDS OF THE HUMAN BODY

CHAPTER XXIV

DEPENDENT ORGANISMS IN RELATION TO MEN

Some Questions this Chapter Answers

Is decay of plants and animals necessary? What living things produce decay? Do freezing and thawing help to produce decay? How does the earthworm live? How do the bacteria live? How are bacteria of help in regard to soils? Are the bacteria that grow in roots of clover, alfalfa, and beans of use to the plants as well as to the soil? Can foods be kept from bacterial decay? How do different kinds of disease bacteria get into the human body? How may their entrance be prevented? What are toxins? antitoxins? What is vaccination? How is diphtheria antitoxin prepared? What insects or other animals are known to carry disease germs? What laws or rules are helpful in keeping the people of a community in good health?

266. What if there were no dependent organisms? What would be the result if there were only building-up processes (see page 357) and no tearing-down processes? If the leaves that fall from the forest trees were to lie for a hundred years they might be pressed down by their weight into a compact mass, but even so, a hundred years' pile of leaves would be several feet deep. If one or two generations of forest trees were to grow old and fall and remain lying on the ground where they fell, the ground would be covered by the remains of past generations of trees.

If all old and dead animals, as well as plants, should remain on the earth we can imagine the earth thoroughly covered by the dead forms of plants and animals of past ages. No room might be left for the growth of new things. Animals would have great difficulty in moving about, but that difficulty would be small compared with others. The greatest difficulty would be that the food material of the earth would be tied up in the dead but undecayed bodies of plants and animals.

In this situation some changes in the dead bodies would be produced by such physical actions as freezing and thawing, by changes in moisture, by sunlight, and by the chemical action of the weak acids that are within the organized bodies; but these destructive changes, so far as they would affect the dead bodies, would destroy them too slowly to keep them from burying living things.

The real story is quite different. As soon as the seeds of corn are planted they are in danger of being eaten by birds or by insects in the ground. While the corn plants are growing they may be eaten by cutworms, corn borers, or other insects or by still other animals. At almost every stage of life both young and old living things may become the food of other living things (Fig. 224). Those that serve as food are disorganized. Their parts are used directly to nourish others or are returned to the soil or air as simpler compounds, such as carbon dioxide, water, or compounds of sulphur and nitrogen. These simpler compounds may then be used again in the never-ending food cycle.

*We have learned that such plants as bacteria, yeasts, molds, and mushrooms secure their nourishment, or food, from organic material which is now, or once was, a part of plants or animals (see pages 384–386). Many kinds of small animals also secure their food in this way. Sometimes these dependent plants and animals are parasites (see page 385), since they get their food from living things. Examples of such parasites are the bacteria which cause disease and the corn borer (see page 363), which eats the corn plant. The plant or animal they live upon is called the *host*. Sometimes they live as saprophytes (see page 385) upon or within dead plants or animals or in soil that contains the products of plant and animal bodies.

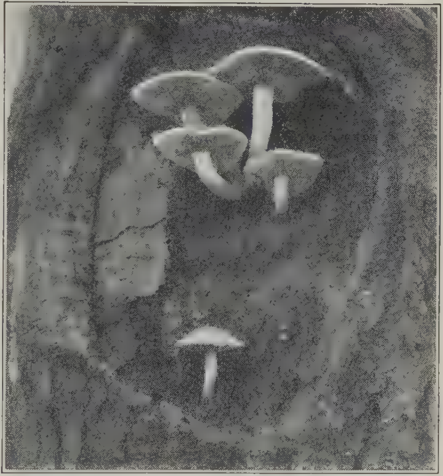

FIG. 224. A TREE-DESTROYING MUSHROOM

The mushroom lives within and upon the wood and helps to produce its decay. (Photograph from the United States Department of Agriculture)

267. Animals as a means of breaking up organized bodies. In a sense all animals are dependent, since the absence of chlorophyll means that at least part of their food is provided by plants. Animals are important means, as are dependent plants, in breaking up organized bodies into simpler form. Parasites may begin the process of tearing down before the host plant or animal has finished with its body. Thus plant lice live upon the stems and leaves of a plant, devour the plant sap, and sometimes are the cause of the plant's death; the locust borer or the peach-tree borer may lay its egg inside the woody part of the locust tree or the peach tree, the egg may grow, and the wormlike young insect, known as the larva, may eat the wood even to the point of making the tree unable to support itself. Other insects lay their eggs in the dead bodies of plants and animals. Their larvæ feed upon or within this home and help to reduce it to simpler compounds. In many cases the larvæ pass into a resting stage within this adopted home, and later come from it in the form of the adult insects like those which laid their eggs. These animals are thus like some of the fungi (see page 384) in living most of the life cycle within their food material.

Possibly no single animal is more important than the earthworm in reducing material to such a condition as to be useful to later plant growth. Earthworms swallow the soil in which there is organic matter. They thrive best in soils containing a large amount of fertilizers or decaying vegetation. As they digest such parts of the soil as they can use they produce important changes in the parts that they cannot digest. A soil in which many earthworms have grown is likely to be a good soil for garden and field crops.

Special Report. Prepare a list of ten of the animals (mammals, birds, reptiles, or insects) of your region, showing in what sense each is dependent and how its dependence helps or harms other living things.

268. *What are the bacteria? The bacteria are one-celled plants belonging to the group called fungi. There are many kinds, most of them extremely small. Some are so small, indeed, that although there is good reason to think that they exist they have never been seen even by use of the most powerful microscopes. Each bacterial[1] cell (see page 355) consists of a thin wall, a small amount of protoplasm and nuclear material which is in small granules[2] and not in a well-organized nucleus. In spite of their simple organization this group of plants is known to have lived even when the oldest fossil records of living things (see page 303) were being made. Moreover, this simplicity does not keep these plants from being of the greatest im-

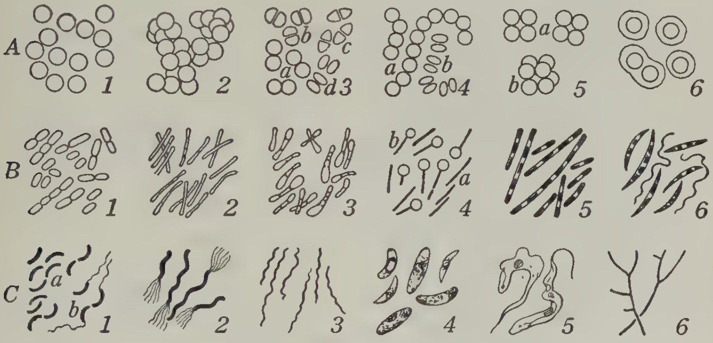

FIG. 225. TYPES OF BACTERIA

A, spherical or coccus forms: *1*, cells separate; *2*, in masses; *3*, *a–d*, in pairs of different kinds; *4*, *a* and *b*, in chains of different kinds; *5*, *a*, in fours, and *5*, *b*, in groups of eight; *6*, with thick walls. *B*, rod or bacillus forms: *1*, a rod form, causes dysentery; *2*, causes tuberculosis; *3*, causes diphtheria; *4*, *a* and *b*, causes lockjaw; *5*, causes glanders; *6*, the curved bacilli, usually found with the spiral forms here shown, cause trench-mouth disease. *C*, spiral, and other forms: *1*, *a* and *b*, causes cholera; *2*, found in water and not a cause of disease; *3*, causes intestinal disease; *4*, causes malaria (an animal form and not bacteria); *5*, a small animal form (not bacteria), causes sleeping sickness; *6*, thread-like forms of bacteria portance to men. Most kinds of bacteria live upon or within decaying plant and animal material; in fact, the bacteria constitute one of the leading groups of the dependent organisms which are causes of decay. Bacteria that cause disease in men, in other animals, or in plants have been objects of keen study for only a little more than fifty years.

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[1] *Bacterial* (bak te'ri al): having to do with bacteria.

[2] *Granule* (gran'ule): a very small piece or particle.

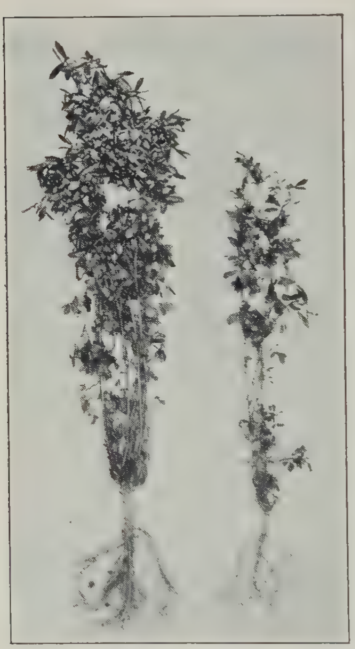

FIG. 226. TWO ALFALFA PLANTS

These plants, grown in pots, had the same care and treatment except that the larger one was in soil which contained the bacteria which form nodules and collect nitrogen from the air. The smaller one was in soil which contained no bacteria. (Photograph by the United States Department of Agriculture)

*In form the bacteria are round (or spherical), curved (or spiral), and rodlike (Fig. 225). The spherical forms may be found in pairs or in chains; the rodlike forms are sometimes joined end to end, thus composing a thread, or filament. It is what bacteria do, rather than their size and form, that makes them of great importance to men.

269. *Bacteria and soils. Some kinds of bacteria, as has already been stated, get their food material from organic matter, and in so doing leave the organic matter in simpler form. The organic matter is therefore ready or more nearly ready to be dissolved in water in the soil, to be taken up by the roots of green plants, and to be used again in the food cycle (see page 414). There are different stages in decay, and different kinds of animals and different kinds of bacteria and fungi may one after another do their particular part in producing this decomposition. Any soil that is fertile for garden or farm plants has in it large numbers of bacteria which thrive, and in so doing make the soil more fertile.

*Among the things most needed by green plants are the compounds of nitrogen. Such compounds are produced through decomposition and decay, but often they are in chemical combinations that cannot be used by green plants. One group of bacteria changes the proportion of oxygen in these nitrogen compounds so that the compounds can be used (Fig. 226); other bacteria, however, change usable nitrogen compounds into those which are not usable, thus doing harm equal to the good done by the first group. Some kinds of bacteria may live in the smaller roots of such plants as clover, sweet clover, alfalfa, beans, and peas. When these bacteria gain entrance within the plant roots, the tissue[1] of the roots enlarges about the

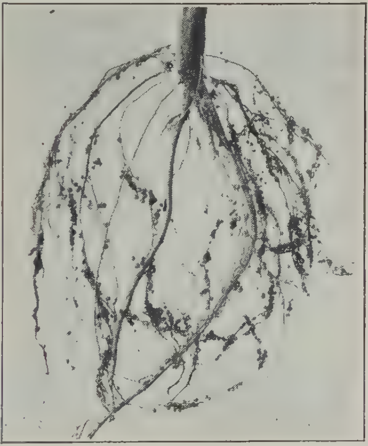

FIG. 227. ROOTS OF A SOY BEAN WITH BACTERIAL NODULES

Within these nodules are many bacteria. (Photograph by the United States Department of Agriculture) bacteria and produces growths called nodules[1] (Fig. 227). The bacteria within the nodules secure nourishment from the plant roots, but they also use nitrogen from the air of the soil and, in using it, combine it with oxygen. The combination of nitrogen and oxygen is in a form that can be used by the plants within the roots of which the bacteria live. The plants help the bacteria by furnishing a home and food; the bacteria help the plants by providing a supply of nitrogen which the host plants can use, and the nitrogen not used by the host plants may remain in the soil for use by later crops of other plants. This is why a crop of clover, beans, or peas makes the soil more fertile. By helping one another the bacteria and their host plants are usually of great help to the farmer.

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[1] *Tissue* (tish'u): a part of a plant or animal made of cells of the same kind.

Special Report. In a field of clover, beans, or sweet clover locate a few thriving plants. Dig the soil away from their roots. Lift the roots with the soil which adheres to them and place them in a pail of water. Carefully wash the soil from the roots. Do you find any nodules? Take the plants to class as a demonstration[2] of nitrogen-fixing bacteria and explain to the class the meaning of the expression "nitrogen-fixing bacteria."

Special Reports. Read in reference books about the relation of bacteria to fermentation, to the making of butter or cheese, and to the preparation of linen and leather, and prepare a class report on one of these subjects.

Experiment 48. Do some kinds of bacteria help plants to grow? Secure two pots of soil from a field in which good crops of clover or beans are growing or have recently been growing. Heat the soil of one pot to 130° F. and keep it at that temperature for twenty minutes; then plant in each pot some seeds of clover and beans. Keep both pots well watered and in a good growing light and temperature. When the young plants are a month old, what difference can you determine in growth and in root conditions? Explain.

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[1] *Nodule* (nod′ule): an enlarged joint or small knot.

[2] *Demonstration* (dem′on stra′shun): the act of teaching by doing before the class.

270. †**When bacterial decay is not wanted.** Bacteria are helpful when they produce decay in things we wish to have decay; they are not helpful when they attack our foods. Since bacteria grow slowly or not at all when in low temperatures, one of the most common ways to prevent decay of food is to keep it cool. Refrigeration (see page 171) is a common means of preventing bacterial growth. The food we wish for future use, however, cannot all be kept in the refrigerator. Such food may be dried and thus preserved, since bacteria cannot grow in the absence of moisture; it may be salted, since salt absorbs the water from bacteria and kills them; and it may be canned by heating to kill all organisms within and by sealing to keep the air from being the means of bringing in new supplies of bacteria or molds (see page 379).

By reference to osmosis (see page 353) explain the action of salt in killing bacteria.

Project. To prepare a class demonstration of two of the best methods of canning any kind of fruits or garden vegetables. Secure the help of the household-arts department in the study of this topic and in making this demonstration.

271. ***Some bacterial diseases.** Several kinds of harmless bacteria are always to be found in the human body. Some of the bacteria found in the intestines[1] may even be

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[1] *Intestine* (in tes′tin): the tubelike lower part of the digestive system.

helpful unless they are present in extremely large numbers, since they help to break up waste material within the body. Usually, however, when we think of bacteria in the body we have in mind those which produce disease.

*The ways in which disease-producing bacteria may gain entrance to the body are known for some kinds but not for all. Those that cause typhoid enter the body with food or water (see page 77). If all the bacteria from persons with typhoid were to be promptly killed as soon as they got out of the patients' bodies it would not be long before there would be no new cases. Typhoid may almost be called the disease which is spread by unclean and careless persons. The germs of tuberculosis may be in milk or when dry may be carried in the air. These germs are widely distributed, and almost all human beings have chances of becoming infected[1] by them. Two facts are highly important in relation to tuberculosis: (1) direct sunlight kills the bacteria causing tuberculosis, if they are not dry; (2) the germs cannot grow so as to produce the disease in human bodies that are kept healthy.

*The bacteria which produce lockjaw, or tetanus, get into the body by way of cuts, tears, pricks, and scratches, and those which produce an infection that may develop into blood-poisoning are introduced in the same way. Therefore it is of the greatest importance that there shall be thorough and prompt treatment of such wounds by use of a disinfectant or an antiseptic. In case of deep wounds the services of a physician should be promptly secured. A soft cloth soaked in a dilute solution of common salt when placed on an open wound prevents the development of infection. Several substances used in solution to prevent growth of bacteria in wounds are available[1] in any drug store.

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[1] *Infect* (in fekt′): to transfer harmful germs to wounds or to well people. This occurs when well people touch objects that have germs upon their surfaces or when well people touch other people whose clothing or bodies carry the germs. *Infection* (infek′shun): the act of infecting or the condition of being infected. *Infectious* (in fek′shus): able to be transferred by infection.

*Common colds are of several kinds, and occur more frequently than any other type of disease. They are spread from one person to another as a result of handling objects that have been used by persons who have colds, or of being too near such persons when they cough or sneeze. Therefore anyone having a cold should not mingle with other people for fear of infecting them. When people cough or sneeze they should always cover the mouth and nose with a handkerchief. Towels, drinking cups, eating utensils, and other objects used by people having colds and other diseases liable to be transferred by infection should be boiled before they are again used. The boiling kills the germs. The best treatment for a cold is rest; one will recover most quickly by remaining in bed, especially if the cold is accompanied by fever.

The advantages of not infecting others in school with some of the common diseases are shown in the records presented in the following paragraph:

In a school in which accurate records have been kept for the past ten years it has been possible to determine what percentage of school time can be saved when proper attention is given to health. Of course some pupils sometimes remain away from school when not ill, and some are in school when ill and in danger of giving diseases to others. When those who may spread disease are kept away, and when it is understood that illness should usually be thought the only good reason for absence, the total percentage of school days that are lost may be reduced. Thus in 1917–1918 in this one school 14.9 per cent of the school days were lost by absence; in 1922–1923 the loss was 8.17 per cent; and in 1927–1928 the loss was 8 per cent. How can it reduce the total days lost to send away those pupils who have infectious diseases?

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[1] *Available* (a vail′a bl): easily obtained or capable of being used to advantage.

*The growth of bacteria can be prevented by use of disinfectants or by germicides.[1] Formalin, carbolic acid, chlorine solutions, and bichloride of mercury in small quantities will act as disinfectants, and in larger quantities as germicides. Chemicals used to destroy bacteria or to prevent their growth should be handled only by those who understand the action of these chemicals. In strong solutions these substances are all poisons. Only very dilute solutions are safe to keep in the home, and even then care should be taken to avoid their improper use.

272. *Toxins and antitoxins. There have been many theories as to how germs cause disease. The one most easy to understand is that the germs use for their own food the body cells (see page 355) and thus produce disease by destroying necessary parts of the human body. No doubt this does occur in some diseases, but it is certainly not the most common way in which diseases are produced. If the germs of diphtheria were grown in a glass tube containing a proper food solution, and if after two or three days they were all killed and the liquid in which they had grown were introduced into the body of a young person who had never had diphtheria, he would probably show all the signs of having the disease. He might then, in a sense, have the disease without having received any bacteria. This is explained by the fact that as the diphtheria bacteria grew in the liquid they produced poisonous substances known as *toxins,* which means "poisons." It is these toxins that cause the disease. Whenever enough of the toxins are introduced into the body the disease follows. Toxins are special products of the life processes of germs, just as carbon dioxide and various other substances are produced in the processes of human nutrition. Each kind of disease-producing germ produces its own particular kind of toxin.

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[1] *Germicide* (jur′mi side): a substance which kills bacteria or animal germs.

*When one has recovered from an attack of diphtheria he does not usually take this disease again, even if the bacteria gain entrance to his body or if the diphtheria toxins are given to him. During the time when he had the disease, his body, in overcoming the toxins, developed substances which counteract[1] the effects of the toxins. These counteracting substances are known as *antitoxins,* which means "opposed to toxins." When enough antitoxin is present the germs cannot grow and thus cannot produce toxins. The diphtheria antitoxin is carried in the blood. The serum, or liquid part of the blood, from a person who has recovered from diphtheria might be given to another person who has never had the disease to protect him against it. Thus the second person would get the protection of having had the disease without really having had it.

*When for any reason a person is protected against a particular disease he is said to be immune[2] to that disease or to possess immunity to it. The person who has had diphtheria and has developed antitoxin, which now protects him against further attacks, has acquired his immunity first-hand; a person to whom antitoxin has been given has acquired his immunity second-hand. Both these persons are said to have *acquired immunity.*

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[1] *Counteract* (koun ter akt′): to act against or in opposition to another action.

[2] *Immune* (im mune′): free from or protected against. *Immunity* (im mu′-ni ty): the condition of being immune, or free from; usually applied to freedom from disease

*There are many people who will not develop a certain disease even if the bacteria of that disease should get into their bodies. For example, some people never have had the mumps, though they have often been exposed to those who had the disease. They are naturally immune, since their bodies are able to prevent the growth of the organisms (as yet unknown) which produce the mumps. A few persons are naturally immune to measles. This kind of protection is called *natural immunity.* Natural immunity usually lasts throughout life, but cases are known of persons who were immune to such diseases as mumps and measles most of their lives and then fell victims to them in their old age.

273. Preparation and use of diphtheria antitoxin. When it was first known that the blood serum from a person who has recovered from diphtheria would enable another person to overcome an attack of it, plans were at once made to secure and keep supplies of antitoxin for ready use. It was soon found that horses and mules, though naturally immune, can be treated with diphtheria toxins and, by successive treatments, develop a high degree of resistance to the disease. In this way diphtheria antitoxin came to be prepared from the blood serum of these animals and made constantly available for any outbreak of the disease.

Throughout the United States there are hospitals and laboratories where this antitoxin is regularly prepared and kept for immediate shipment whenever a physician calls for it. When properly prepared and properly given at the beginning of an attack of diphtheria, antitoxin saves nearly all those who receive it. When it is given on the second day of the disease, less than 10 per cent of the patients die; when given on the third day, about 20 per

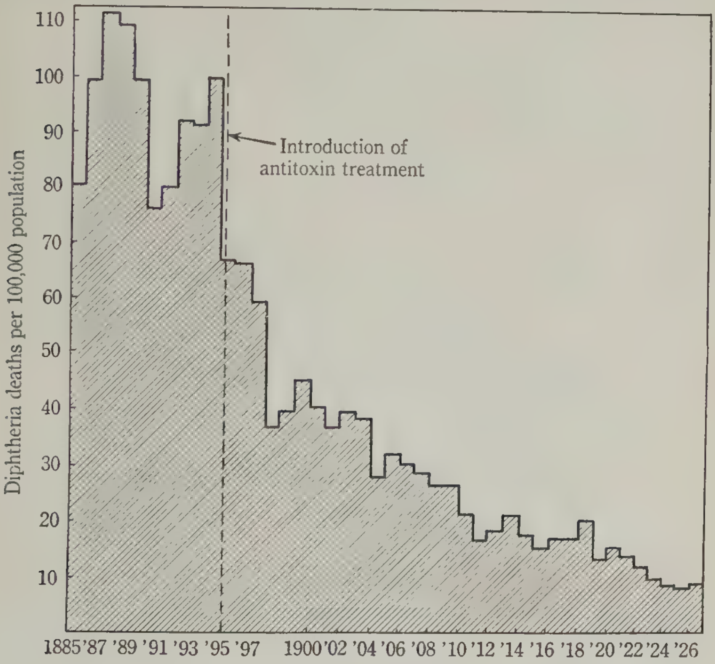

FIG. 228. GRAPH SHOWING THE RESULTS OF THE USE OF DIPHTHERIA ANTITOXIN

This graph shows that in 1885 on an average 80 people out of every 100,000 died of diphtheria; and that in 1888 an average of about 111 people out of every 100,000 died of this disease. In 1895 antitoxin was introduced in treating diphtheria. The graph shows that at once the death rate from this disease began to decrease rapidly. In which year since has there been the smallest death rate from diphtheria? What was the average number of deaths per 100,000 population from this disease in that year?

cent are lost; on the fourth day, from 25 to 30 per cent are lost; on the fifth day, about 40 per cent are lost; and if not given until after the fifth day, over 50 per cent are lost, — the toxins have then become too abundant for the prepared antitoxin to be very useful.

The records given in Fig. 228 should prove convincing as to the value of diphtheria antitoxin. There have been occasional failures to use properly prepared antitoxin or to use it in the right way, and much has been made of these unfortunate occasions by those who oppose modern health practices. But the occasional poor work of a railway engineer does not prevent us from using railway trains; instead we try to get rid of poor work. Boards of health and public-health officers are appointed to attend to the business of reducing poor work and seeing that proper things are done for the people's health.

> ***Special Report.*** Secure from your city or state health department the published records of the amount of diphtheria in your city or state and prepare a report showing what was done and should be done to prevent this disease.

274. *Vaccination[1] as a protection against disease. Long before the nature of bacteria or of small animal parasites was known a very important discovery was made by an English physician named Jenner. He noted that those who milked cows which had a disease called cowpox sometimes took the disease, and that after recovering from it they were immune to smallpox. Some people even advised those who wished to become immune to smallpox to milk cows until they got the cowpox. Jenner devised a plan for directly infecting a person with a small amount of material from the cowpox eruption.[1] By so doing he could transfer the disease to human beings, who after a mild attack were immune to both cowpox and smallpox, which are now thought to be the same disease. This process was called *vaccination.* The process has been improved in methods since Jenner's time, but the principles were discovered by him. It is now thought, although it has not been finally proved, that very small animal parasites and not bacteria are the germs of smallpox.

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[1] *Vaccination* (vak′sin a′shun): the process of introducing a mild form of disease by use of weakened or dead germs or of the products from these germs. In vaccination a person is infected with germs which produce a mild form of disease.

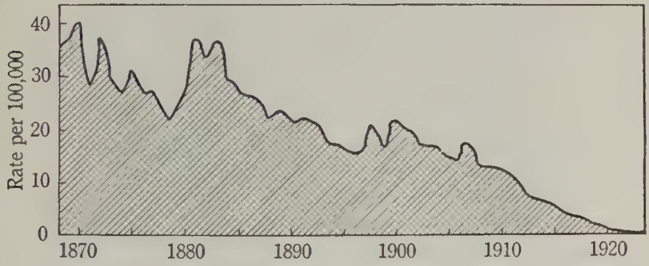

FIG. 229. GRAPH SHOWING THE DECLINE IN DEATHS FROM SMALLPOX

The graph shows that in 1870 an average of about 40 people out of every 100,000 died of this disease. In 1913 this death rate had decreased to about 13 in every 100,000 population. What was the death rate in 1900 and in 1925?

†Jenner thought that the germs lose their strength in the bodies of cows and soon die. He thought it likely that the weakened germs which attacked those who milked the cows produced mild attacks of the disease, and that in overcoming these mild attacks the body gained ability to prevent further attacks. Thus vaccination against smallpox by use of weakened germs has now become a common practice by all people who use modern knowledge for the best interests of their health.

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[1] *Eruption* (e rup′shun): a rash on the skin.

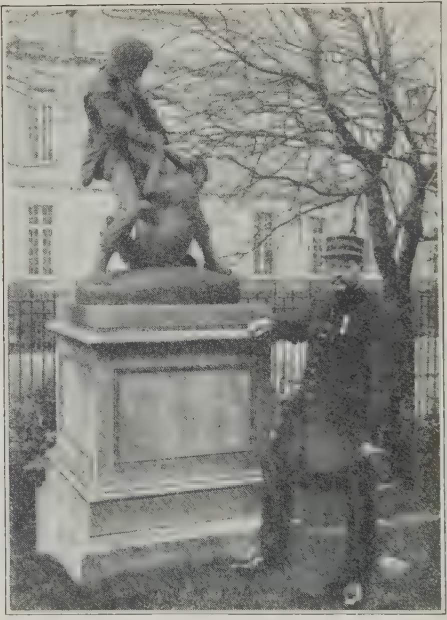

FIG. 230. A MONUMENT TO LOUIS PASTEUR

Louis Pasteur (1822–1895) was a French scientist. With his microscope and his careful, exact methods of study he proved that bacteria float in the air and if kept out of foods no decay will result. He proved that fermentation may be caused by yeasts from the air. He saved the silk industry of France by finding the germs that killed the silkworms. He found how to control the germ of chicken cholera, which took 10 per cent of the French fowls every year. A disease called anthrax was killing cattle and sheep. Pasteur found how to prepare vaccines and to treat the animals so that they became immune. Hydrophobia, fatal to man, was conquered by vaccine prepared by Pasteur. A boy, Jufille, was bitten by a mad dog while trying to protect some younger children. Pasteur treated the boy and he recovered. This picture shows Jufille, now a man, beside the monument to Pasteur. The antitoxins used today have been developed upon Pasteur's foundation work.

Pasteur was a noted pioneer in the study and use of vaccine, especially that for hydrophobia (Fig. 230).

*The methods of vaccination vary in each disease for which a method of vaccination has been discovered. Use is made in typhoid of a series of vaccinations with dead typhoid bacteria and their products. Recovery[1] from the slight discomfort of the first vaccination leaves the body better able to meet the second, and recovery from the second prepares for the third. After this the fully active typhoid bacteria cannot get started; that is, the body becomes immune (Fig. 231). Immunity to typhoid may last for several years, but is not sure to last for a lifetime.

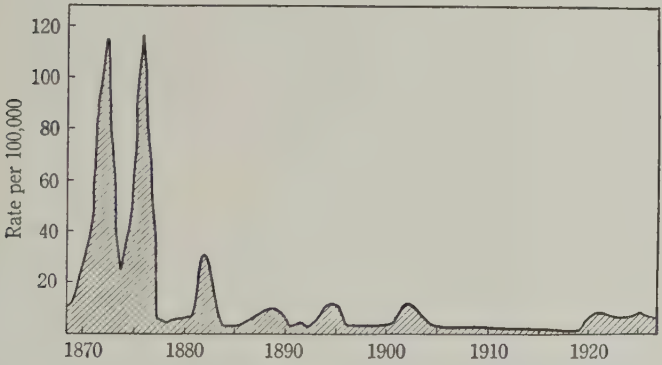

FIG. 231. GRAPH SHOWING THE REDUCTION IN DEATHS FROM TYPHOID

This graph shows that in 1873 on an average about 117 out of every 100,000 people died of this disease. The death rate from typhoid decreased greatly from about 1877. From the early 80's there were on an average fewer than 10 deaths per 100,000 population. In which year since has the death rate from typhoid been smallest? What was the death rate in that year?

*In vaccinating hogs for hog cholera another plan is commonly used. Weakened but living bacteria and a small amount of antitoxin are given at the same time. As the bacteria begin to grow the presence of the antitoxin enables the animal to counteract the toxins and to produce its own antitoxins, thus producing immunity. Sometimes only antitoxin is given, with the aim of protecting the animal against possible natural infection. This is not so effective as the double vaccination.

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[1] *Recovery* (re kuv′er y): getting well after an attack of disease.

These are types of the production of immunity by the use of antitoxins and vaccination. It must be understood, however, that in the treatment of human diseases many variations are made of the processes used. There are some diseases of which we do not know the cause or any way to guard against them.

275. Disease germs carried by insects and other animals. The cattle tick, common in southern United States, is a small insect which bites through the skin of cattle and feeds on the blood. If this tick has in its own body any of the bacteria which cause cattle fever (as it often does have), some of these may get into the blood of the cattle and produce this disease. The bacteria can live for long periods within the ticks, and therefore these insects are a constant danger in the warmer parts of the United States. The cattle may be "dipped." Dipping consists in immersing them entirely in a liquid containing an insect poison (Fig. 232). This process should be repeated as often as the ticks appear. Another most interesting method of preventing this disease consists in developing cattle with skin so thick that the ticks cannot bite through it.

*The disease called malaria or malarial fever, formerly very common, is produced by a small one-celled animal parasite. This germ lives in the body of a certain kind of mosquito. When this mosquito bites a human being the germ may get into the blood, where it rapidly produces many of its kind. It lives in the red blood corpuscles (see page 470) and uses them as its food. Whenever a large number of the young parasites escape from the corpuscles into the liquid of the blood the sick person has a "chill." If this person has taken quinine, this also is in the serum of the blood and may kill the parasites. Mosquitoes with no malarial germs may get them by biting people who have malaria. In fact, the parasite must spend part of its life in the human body and part in the body of the mosquito. The mosquitoes also have the disease.

*Yellow fever is also caused by an animal parasite. This one lives in the body of another kind of mosquito. Its way of living is much like that of the malarial parasite — part of its life in the body of the mosquito and part in the human body. Both diseases may be prevented by avoiding bites from these kinds of mosquitoes. The surest plan is to destroy

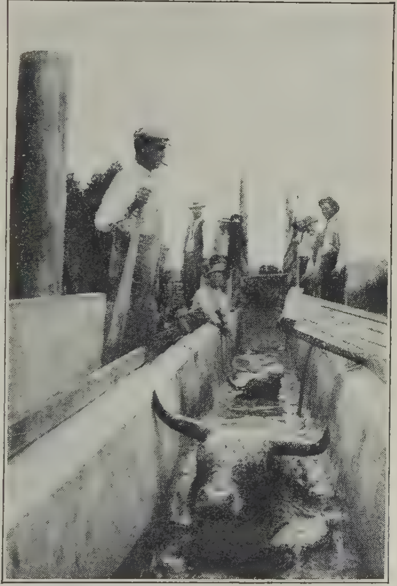

FIG. 232. DIPPING CATTLE TO DESTROY THE CATTLE TICK

Deep tanks are filled with the antiseptic solution. The cattle are made to go through these tanks. What seems like rough treatment is really kindness, since the health of the cattle is greatly improved by it the mosquitoes that carry these germs. This may be done either by draining the lakes, pools, or other places where there is standing water or by pouring crude oil (see page 315) or kerosene on the water. The oil prevents the young mosquitoes from getting air and thus kills them.

Local, city, state, and national health officers are charged with the responsibility of helping to get rid of the kinds of mosquitoes that carry disease germs.

*Flies are probably among the most common agents of distribution of bacteria of many kinds. Flies lay their eggs in almost any kind of organic waste material; therefore it is very difficult to prevent them from reproducing in large numbers. There are flies wherever people are not careful to dispose of wastes. The number can be kept small, however, if everyone makes it his business to see that there are no manure piles, garbage piles, or other similar waste materials in which the flies may lay their eggs.

Special Reports. Prepare a class report on the mosquitoes or flies which carry disease germs, and discuss in class the measures that are or should be taken to prevent them in your vicinity.

276. †Other animals in relation to health and comfort. We have discussed some of the common animals (Chapter XXIII), such as birds, insects, snakes, and household pets. In houses and other buildings used by men, many other animals have also learned to make their homes. Rats and mice are often serious pests.[1] They eat both fresh and stored food of almost all kinds, and spoil part of the food they do not eat. Rats are known to be carriers of the germs of bubonic plague and may possibly carry other germs. Fleas and other insect pests are likely to be found wherever rats and mice are allowed to live.

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[1] *Pest*: something which annoys and harms.

> *Special Reports.* Secure from the United States Department of Agriculture the most recent bulletins on rats and mice and prepare an outline of the reasons for disposing of these animals and the best methods of doing so. Do the same for ants and cockroaches.

†Insects such as clothes moths, bedbugs, and buffalo beetles (Fig. 221, p. 405) are common in sleeping and living rooms. The moth lays its eggs on woolen cloth. The egg hatches into the larva; the larva eats the wool, and when it is ready for its resting stage it makes its cocoon from the woolen material. Sunlight is the greatest enemy of the egg, larva, and adult moth. The moths can be killed when found, but all woolen clothing should be put in the air and sunshine to kill any eggs or larvæ that may be on it. Bedbugs, which live in blankets and quilts and in the cracks of beds, and buffalo beetles, which live in carpets and in cracks in floors and walls, may be disposed of by washing the floors and walls, by placing the blankets, quilts, and carpets in the sunshine out of doors, and by thorough treatment of beds and floors with poisonous washes and insect powders.

277. Whose business is one's health? It is almost true, but not wholly true, that anyone who was born with a good sound body may have good health if he really wants it. If he eats the proper amount of good food, gives his body proper exercise and fresh air (see page 223), sleeps well and enough, and keeps clean, he has laid the foundation for good health. One person, however, cannot entirely control his own surroundings. Diseases do sometimes develop which could not be prevented. Very many cases could have been prevented, however, by proper care.

The *desire* to have good health can hardly be given too high a place in one's life, for it causes us to do the things necessary to secure and maintain health.

*To care for the health of the community and to prevent the spread of disease we have laws (1) for the disposal of household wastes (Chapter VII), (2) for disposal of city wastes, (3) for disinfecting houses where there have been infectious diseases, (4) for quarantining persons or regions that have infectious disease, (5) for regulating milk, water, and other food supplies, (6) for reports on cases of sickness and death, — in fact, laws made to provide and to keep proper conditions for good health for all. There are local, state, and national officers and organizations whose business it is to know the laws and to see that they are enforced. It is the duty of every good citizen to help in every way to enforce these laws.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. All bacteria are simple one-celled animals.
2. In shape bacteria are ____, ____, and ____.
3. A clover crop makes the field more fertile because of the action of insects which live within the clover roots.
4. A disease which is cured by the use of antitoxins is catarrh smallpox diphtheria rheumatism heart trouble.
5. A disease which is prevented by vaccination is catarrh diphtheria rheumatism mumps smallpox.
6. A disease which is prevented by giving a series of vaccinations is catarrh diphtheria smallpox measles typhoid fever.
7. Two diseases which are known to be carried to man by mosquitoes are ____ and ____.

CHAPTER XXV

FOODS AND THEIR USES

Some Questions this Chapter Answers

Are the daily "three meals" necessary? What three important uses do foods serve? What three groups of foods are most important? What is the purpose of a mixed diet? Why should fruits and vegetables make up a regular part of the diet? What are the names of the different vitamins, and of what use is each? What special values has milk as a part of the diet? What are the sources of milk in different countries? What are the sources and uses of sugar? What are food substitutes? food adulterants? Are food substitutes always undesirable? Are food adulterants always undesirable? What are the chief methods of preserving foods?

278. Early foods and food habits. The habit of having three regular meals a day is not one of the oldest habits. It was only after food became fairly abundant and after it became known that the body works best with several meals of smaller amounts rather than an occasional very large meal, that this system came into use. Probably the first men ate abundantly whenever they had a chance to get food, then there was a long period before they ate again. They probably ate their plants or vegetables with little or no preparation (Fig. 233). Since wild vegetables were usually easier to get than animal food, it is likely that vegetables made up the regular diet and that animals were an irregular part of it. It is likely also that when animal food was procured, there was a tendency to devour it in larger amounts than if it had been regularly available.

FIG. 233. A MODERN FRUIT MARKET

How many kinds of fruits here shown do you know and use?

It is known that when primitive men had gone for long periods without meat they sometimes ate many pounds of raw meat. The smaller and less desirable animals, such as snails, clams, mussels, and insects, were not hard to catch; the more desirable ones, such as squirrels, deer, bear, and buffalo, were harder to secure and probably were hunted actively only when hunger for meat became pressing.

As men advanced in knowledge, a knowledge gained by experience, they began to think ahead to future needs. They learned to secure both animal and plant food and to save at least part of it for a later time when they might perhaps be more hungry. In the warmest parts of the earth foods of some sort may have been available all the year. If men wished to live away from the tropics they *must* look forward to the time when no plant food except that which was saved could be had and when animals might be less abundant and less desirable for food than in summer weather. Men also needed clothing and homes for use in colder weather, and they learned to meet such needs before the needs actually came. One of the best evidences of civilization is shown by the ability and the habit of preparing for future needs. It is not an accident that the people of the temperate zones are often those who have the vigor, industry, and ability to plan for the future. If at least a considerable part of these people did not have these qualities they could not live through the cold winters of these regions.

279. *Our needs for food. There are three main services performed by food: (1) building up the body by replacing worn-out parts, (2) providing the materials for growth, and (3) providing energy by means of which the work of the body is done. The needs and uses of food in the body are sometimes compared with needs and uses of fuel in a machine, such as an automobile. The comparison cannot be carried too far, else it may not be accurate. For example, the body can use the digested foods to replace and build up worn-out cells, while the automobile must go to the repair shop for the repairing or replacing of worn-out parts. When human foods are digested they may be used for growing new parts or for enlarging old ones, while a machine such as an automobile must have new parts built in. Foods are used and oxidized (see page 151) as a source of the energy by means of which work is done; in an automobile, fuel is oxidized and used as a source of the energy which drives the machine.

The gasoline vapor and the air that is mixed with it explodes in the cylinder when the oxygen combines with the gasoline. The energy thus released drives the pistons, and this causes the car to move. In the living protoplasm of the cells (see page 355), oxygen combines with the various compounds, and energy is released by means of which all kinds of work are done. When oxidation occurs heat is produced. Thus the real source of the heat of the body is the using of the food by protoplasm.

†Anything that can be used by the body for building new parts, for growth, or for supplying energy may properly be called a food. These foods are almost wholly made from ten chemical elements, though some other elements are found in the body in small amounts. The ten elements are carbon, hydrogen, oxygen, nitrogen, calcium, potassium, magnesium, sulphur, phosphorus, and iron. It is not fully known whether all the other elements found in the body are necessary. Possibly some of them are brought in with food material and deposited in the body without serving any useful purpose. Silicon and chlorine are also usually found in both plants and animals.

*The compounds made from these elements make up three groups of foods: (1) the *sugars and starches*, or carbohydrates (see page 351), usually secured from ripe fruits, potatoes, rice, and white bread; (2) the *fats*, usually secured from milk, butter, oleomargarine, peanuts, peanut butter, and other nuts and nut-food preparations, oil dressings for salads, and fat meats; (3) the *proteins* (see page 351), usually secured from such sources as beans, peas, lentils, bread, eggs, lean meat (Fig. 234), and fish. Mineral substances such as salt, lime, and iron compounds are needed and are supplied in milk, vegetables, and fruits, or they may be added, as is done by using salt.

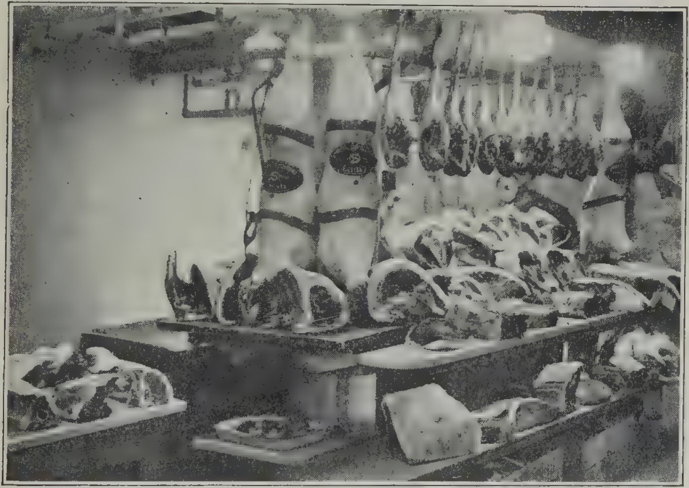

FIG. 234. A MODERN MEAT MARKET

After studying this picture, make a list of kinds of meat you know that are not here shown

280. Mixed and balanced diets. When one has been working vigorously for several hours, for what kind of food is he usually most hungry? When one has been in school for hours, or has tramped miles in the country, or has been skating, what kind of food is chiefly desired? When a carpenter or a harvest worker comes in from his day's work, would he rather have his dinner start with meat, potatoes, gravy, and bread or rolls, or with pie, a jelly dessert, and candy?

*Protoplasm is a protein, and when hard work is done, part of the protoplasm of the cells is broken up. When hard work is done with the muscles (see Chapter XXVI) more protoplasm is broken down than when hard desk work is done. The body needs protein foods to build up the protoplasm that has been used while work was being done. The sugars and starches and other carbohydrates are used chiefly for the energy they contain (see page 356). This energy may be released for use by oxidation within the body cells. Carbohydrates are also used as the basis for making fats and proteins. Fats are used directly as foods or are stored in the body for later use. It is clear, therefore, that a diet should include foods from each of these three groups if all the needs of the body are to be met. In younger people, who are growing rapidly and who take much vigorous exercise, protein foods are constantly needed to replace and build new protoplasm, and both proteins and carbohydrate foods are needed to keep up the supply of energy. The proportion of fats required for young people is less than for fully grown people.

Not only should the mixed diet include foods from each of the three groups, but it should be properly balanced in quantity from each group. It is not possible to state exactly what this balance is for all people. Each must find what proportion works best for himself and then follow his conclusions. Each meal, however, should include proteins from some such foods as soups, meats and fish, beans and peas, and rye or whole-wheat bread, and carbohydrates from fruits, potatoes, carrots, and other vegetables, jelly, and desserts. The needed amounts of fats and sugars are likely to be present in these foods in sufficient amounts. This is true if sugar is used in preparing fruits and desserts.

281. Fruits and vegetables. There is little danger of urging too strongly the importance of using fruits and vegetables in our daily food. For ages the human body had to secure its nourishment (in large part at least) from bulky[1] materials such as plants and parts of plants. In doing this the structures and habits of the digestive[2] system became fitted to the tasks of securing food from these bulky materials. We are not properly fed when we have all our needed nourishment in the most concentrated[3] form. We could have all our meals consist of protein in the form of extracts of meat, beans, and peas; all our vegetable juices in concentrated vegetable jellies and stews; all our fats in pure lard and butter. We could even add the welcome flavoring extracts and salt and pepper to these concentrated foods. Such an arrangement would not give us satisfactory meals either from the point of view of taste or from that of nourishment.

The teeth and muscles of the mouth are used in chewing food. This is not entirely in order that we may be able to swallow the food, since digestion begins in the mouth. Chewing helps to mix the food with the fluids formed in the mouth, and thus helps digestion to get started. It also helps to insure the needed time for the beginning of digestion in the mouth.

Other parts of the body, such as the stomach and intestines, are also adjusted to securing food from bulky sources and do their work better when vegetable foods are used.

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[1] *Bulky* (bulk′y): occupying much space.

[2] *Digestive* (di jest′iv): having to do with digestion.

[3] *Concentrate* (kon′sen trate): to put much in a small space.

A chemist might discover ways of feeding himself such prepared and concentrated foods that almost all the work of digestion would be avoided. The result of his effort would probably be, however, that he would have indigestion.

Vegetables and fruits are needed daily. They must be well chewed, or part of their most important service to us will be lost. It is possible to cultivate a taste for most kinds of vegetable food as well as for animal foods. Tastes are most easily established in one's early years. Those whose tastes are too limited should train themselves to eat the food that they know is best for them to eat.

282. *Vitamins. This group of "body regulators" has been known for but a few years; but though they are not yet well understood they are known to be of great importance. Sources of the vitamins are known and the effects they produce in the body, but scientists have not yet found how they produce these effects. Each of the vitamins has been named by a letter and by words that suggest something about it (Fig. 235).

One vitamin is found in green vegetables and in animal fats, and is known as fat-soluble vitamin A. This vitamin helps in the development of the eyes and in preventing diseases of the eyes. For example, the eyes of young rats that are fed good food but food from which vitamin A has been removed do not develop properly. Sometimes the eyes do not develop at all. Older rats that are not given vitamin A are likely to have certain eye diseases. These diseases disappear after vitamin A is added to their food. It is thought that this vitamin bears the same relation to the eyes of children.

Water-soluble vitamin B is secured in the coverings of such grains as rice. Animals (including human beings) that are fed on polished rice — that is, rice grains from which the hard coat has been removed — have weak bone development and lose the ability to walk without staggering. This disease is cured by adding vitamin B to the diet.

Vitamin PP, from yeasts, milk, and meat, has been found to prevent the disease known as pellagra.

Vitamin C is secured from acid fruits (see page 116), such as oranges, apples, and pears, or from tomatoes.

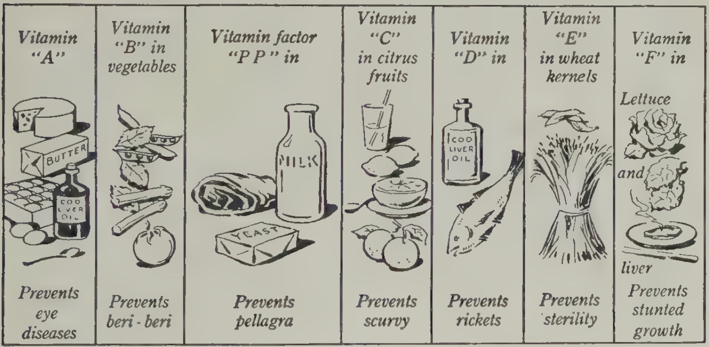

FIG. 235. A VITAMIN DIAGRAM

Seven vitamin factors have been discovered, each having special functions. A well-balanced diet of milk, meat, fish, fruit, and vegetables is necessary for growth and health. (By courtesy of *Science News Letter*)

A skin disease known as scurvy develops in the absence of vitamin C. This disease can be cured by adding fresh fruits and vegetables to the diet.

Vitamin D, found in cod-liver oil, prevents rickets. Rickets is a disease much like that which develops when vitamin B is absent from the food, but the two diseases are different and are prevented by different vitamins. It is also known that direct sunlight helps to prevent rickets.

Vitamin E, also found in vegetables, has an important influence on the production of offspring in certain animals with which experiments have been made. In these experiments absence of vitamin E in the diet of either males or females has resulted in few or no offspring.

Vitamin F, found in vegetables such as lettuce, and in liver, is a factor in proper growth of young animals.

Still other vitamins have been reported, and studies are being made that will no doubt furnish additions to this list.

Scientists at first believed that vitamins were largely destroyed when foods were cooked or canned. It has since been found, however, that this loss occurs only when the foods are cooked in open kettles. Here the air is around the foods with the result that oxidation is increased, destroying the vitamins. When fruits are preserved by cooking them in cans or jars so that the oxygen of the air does not have a chance to get to them, the vitamins are not only not destroyed but will remain in the foods for years. Commercially canned fruits and vegetables, as they are usually canned, are better sources of vitamins than home-cooked fruits and vegetables, because they are cooked away from the air. It has been found, moreover, that raw foods, such as apples and vegetables, lose much of their vitamin content when they are kept for some time before they are eaten. To save the vitamins in such foods, therefore, it is best to can them by the cold-pack method immediately after they are harvested.

283. †The importance of milk. Milk is the universal food. Not only is it used all over the world, but it is used by all classes of people who can get it. Even those adults who do not drink milk use it in their other foods. Milk is the first food of all those animals, including man, known as mammals (see page 409). Indeed, it would be more appropriate to call this whole group the milk animals than to call them mammals, since the name mammals refers to the structures which produce the milk and not to the milk. The milk itself, however, *is the really important thing*. The young of all animals except mammals must depend upon foods other than milk for getting started in the world.

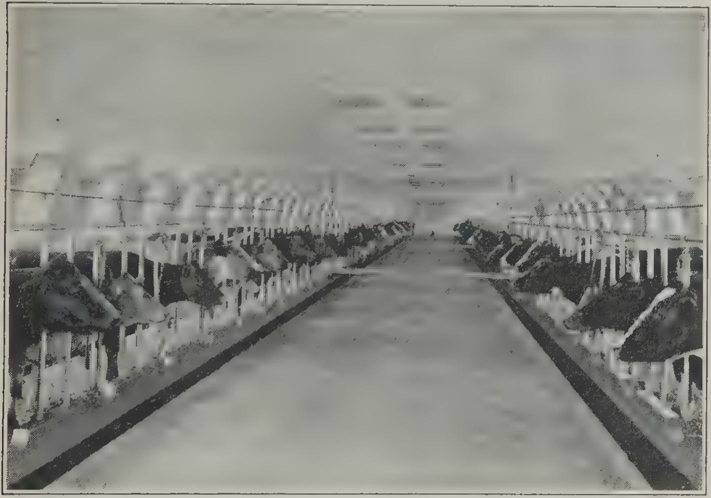

FIG. 236. A CLEAN DAIRY BARN

What features make it easy to keep this barn clean?

†Milk contains sugars, fats, and proteins in forms that are most readily digested and absorbed. The butter in milk contains one of the most important of the vitamins. Calcium in milk is necessary for building bone tissues. Milk is the perfect food. Unless a physician has advised that a special diet should be used, every pupil of school age should drink milk every day. The use of milk is constantly increasing and seems likely to increase still further.

284. Raw milk and prepared milk. Milk is made available in several forms. Milk delivered to customers without treatment is known as raw milk. When such milk can be had from clean dairies (Fig. 236) and brought to the homes without having any undesirable things get into it, it is to be preferred to milk in any other form. Raw milk is more wholesome, tastes better, and is more easily digested than milk in other forms. But the milk must be clean and free from disease germs if it is to be used as raw milk (Fig. 237). Careless handling of raw milk has been the means of distributing the bacteria which cause throat infections, typhoid, and other diseases. The proper cure for these dangers is substituting care for lack of care. This can be done when the health officers and milk producers do their full duty in guarding the public's welfare.

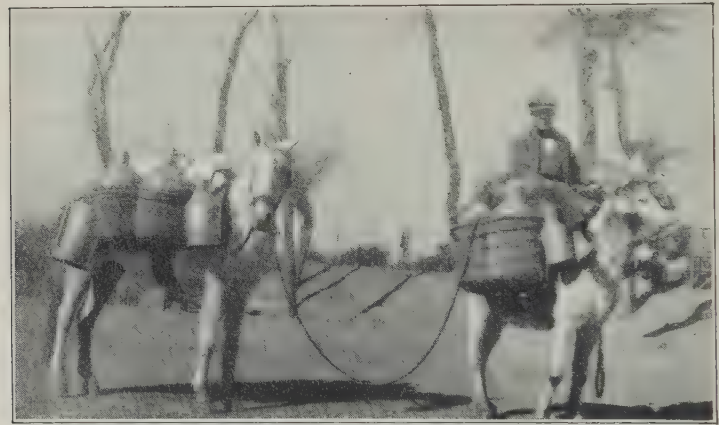

FIG. 237. DELIVERING MILK IN GRENADA, SPAIN

List the advantages and the disadvantages in this method of delivering milk

Milk which may not be safe should be *pasteurized*; that is, it may be heated until it reaches a temperature of from 142° F. to 145° F. and kept at that temperature for thirty minutes and then promptly cooled to at least 50° F. Pasteurizing small amounts of milk may be done most safely by using a pan of water in which the milk bottles are stood upon a false bottom that will raise them above the bottom of the pan. The milk should not be allowed to boil, since boiling cooks it and thus causes changes in the food values of the milk. Indeed, some changes which are usually produced in pasteurizing are not desirable. Pasteurized milk is safer during a period when disease is common or when a question arises as to whether the raw-milk supply is free from bacteria which might produce disease.

Milk is also concentrated by evaporation and preserved in tin cans. In this form it may be shipped any distance and may be kept so long as the tins are not opened. Milk is also dried, and in this form may be shipped and kept for future use. When needed, the milk powder is mixed with water and may be used for drinking and in cooking other foods. During the past twenty years factories for condensing milk by evaporation or for drying it have become common in farming regions which are not close to large cities. Trucks from these factories are driven daily through the surrounding country to gather the cans of milk and leave fresh cans for the next day's production of milk.

285. †Sources of milk. For the youngest animals, including human beings, the mother's milk is likely to be best. The supply of the mother's milk in most animals is limited and with human beings is often not sufficient for the proper growth of the baby. For this reason and in order to have milk for drinking and cooking, it has been necessary to secure milk from several kinds of animals. In Italy and some other European countries goats are kept for their milk. This practice has recently become fairly common in the United States. In Palestine it is not uncommon to see sheep used for their milk. In some of the Spanish countries the milk of mules is used. The water buffalo is the chief milk-producing animal in Egypt, India, China, and many other countries.

In some of the countries which do not have satisfactory ways of keeping the milk cool, the milk animals are led or driven about the city streets. When a person wants to buy milk, the milkman stops his herd, milks the desired amount, delivers it, and then moves his herd on to his next customer.

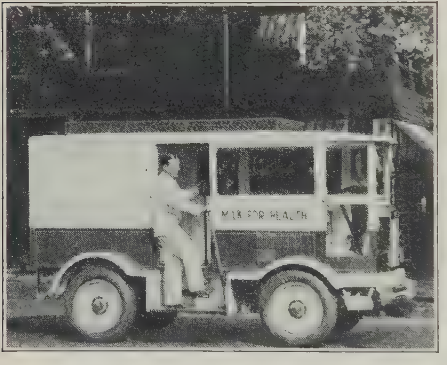

FIG. 238. DELIVERING MILK IN DETROIT, MICHIGAN

What advantages has this method of delivering milk over that shown in Fig. 237? (By courtesy of *Popular Science Monthly*)

Milk cattle of several kinds are the world's chief source of milk. During the past hundred years much attention has been given to the development of improved breeds of dairy cattle. The quality and quantity of milk have been improved by selection and care of these cattle, and very high standards have been reached. The production of milk of good quality is now one of the large industries in the United States (Fig. 236). In large cities milk is delivered in specially designed automobile trucks (Fig. 238).

286. †Sources of sugar. The human race seems always to have had a "sweet tooth." This is natural, since a proper amount of sugar is a necessary part of one's diet. A balanced diet requires that an excess of sugar, like an excess of any food substance, be avoided. The pleasing taste of sweet things has caused many people to develop a sugar appetite in excess of what is good for their proper nourishment. The earliest settlers in this country found it difficult to secure enough sugar. The sugar-maple tree in springtime provided a sweet sap which could be boiled and thus evaporated until a thick sirup[1] was produced; or the sirup could be boiled still further until it made solid sugar. The boiling is the means of evaporation, and the sugar is left when the water is gone. When other sources of sugar became abundant, maple sirup and maple sugar came to be thought of as luxuries.

Honey was also a source of sugar in early days, as it is still. The wild bees, with homes in hollow trees or rocky ledges, stored honey which they had made out of nectar from flowers (see page 364). In modern times bees have been improved by selection and care, and the annual production of honey in the United States is steadily increasing. Although honey is more or less a luxury, it also is a common article of food all over the world.

†Sugar cane and sugar beets are the chief modern sources of sugar. In the southern part of the United States, in Cuba, in the Philippines, in the Hawaiian Islands, and in many other tropical countries, sugar cane is one of the most important crops; and the growth of sugar beets has become one of the leading farming interests in many of the Central and Western states, as it is in

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[1] *Sirup* (sir′up): a thick, sweet liquid made by dissolving sugar or by evaporating the water from sweet sap.

Germany, France, and other countries with temperate climates. The United States now produces large quantities of sugar from sugar beets and from sugar cane.

287. *Food substitutes and adulterants.[1] It often is possible to sell as food a substance which is not what the buyer thinks he is buying. It is often possible to use instead of one food another which has about the same food value but costs less, or which may be secured when another cannot be had. A food to be used instead of another is called a food substitute, as when oleomargarine is used for butter. The substitute may be quite acceptable as a food and may be colored or flavored to look or taste like the article for which it is substituted. Many substitutes of chemical origin are now sold.

> Why should it be necessary for these to be sold as substitutes?

*When a food is mixed with or consists of a substance which changes its nature or its uses as a food, it is said to have been adulterated. The adulterant is the substance added to the food. Thus when what is sold as coffee is partly coffee and partly other plants, the coffee is adulterated.

There is a United States Pure Food Law, and many states have separate laws which demand that manufacturers shall label their food articles so as to show just what these contain. The labels for substitutes and adulterated foods are often so worded that many purchasers do not really know that they are buying substitutes or adulterated foods. In some states the laws do not fully protect the public or are not enforced by the local authorities.

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[1] *Adulterant* (ad ul′ter ant): an impurity put into foods or other materials to reduce the cost of manufacture.

Special Reports. How many kinds of substitutes or adulterated foods can you find from a grocery or drug store in your community? Secure help from some dealer in foods who will allow you to make an exhibit to your class of food substitutes or adulterants labeled so as to seem to be one thing when they are another. Secure reports from your state or city food inspector regarding particular work done by his office in studying and testing the purity of foods. Make a class report on this topic.

288. *Preservation of foods. Drying was an early method of preserving. The Eskimos still dry fish in great quantities. Other peoples learned to dry the flesh not only of fish but of almost all kinds of meat-producing animals. In drying, almost the whole food content is preserved, and when dried meats are cooked slowly in water they make excellent foods. Drying is also used in making raisins (Fig. 239) from grapes and in preserving many kinds of fruits and vegetables. Raisins are a most wholesome food. The United States uses large quantities each year, almost all produced in California. The clear, dry, sunny weather of the grape-growing region of California serves both to produce great fruit crops and to dry them for the markets.

*Salt is much used in preserving meats. Preserving by salt may cause the meat to become hard, but soaking in cold or warm water before cooking will remove most of the salt and will soften the tissues. Salted meats are sometimes smoked. The smoke added to the salt helps to preserve the meat and also adds a desirable flavor. The salting and smoking of "country-cured meat" are slow processes. Many people, however, prefer meat which has been so cured to that preserved by the more rapid salting with salt solutions and the smoking with chemicals, which is accomplished by use of compressed air in large meat-packing establishments.

*Canning as a means of preserving is based on the principle of heating the food sufficiently to kill bacteria, yeasts, and molds, and then of closing the can or jar air-tight while hot, so that no new bacteria, yeasts, or molds may enter. Almost all kinds of foods are now preserved either in glass or in tin cans. Canning establishments are now found all over the country wherever foods are produced. Thus much food which would otherwise be spoiled and lost is saved. The canning of food makes it possible for people to have a wide variety of foods at all times of the year in all parts of the world; also we may know and use many kinds of foods which our grandparents never knew.

FIG. 239. MAKING RAISINS FROM GRAPES IN CALIFORNIA

Special Report. With the help of your grocer make a list of all the different canned fruits, meats, and other canned foods to be found in a grocery store.

Refrigeration is a favorite means of preserving (see page 170). Meat-packers regularly keep large quantities of meat at low temperature.

Foods should not contain any preserving substances harmful to the human body. Formalin or any other poisonous substance used to prevent growth of bacteria and molds is likely also to be of harm when eaten in foods. Milk is sometimes treated with small amounts of certain chemicals. When milk that is left for a day at a temperature of about 70° F. does not sour, the health officer should be asked to determine if preserving substances have been used. Sugar, spice, salt, and vinegar are considered harmless preserving substances for foods.

289. Preparation of food. There are many ways of preparing foods for use. The same food may be prepared in several ways at different times or by different people. Salads are mainly uncooked. Fruits are used raw or cooked. Fruits are preserved by cooking or drying, to be either cooked later or used as they are.

Meats are almost always cooked before they are used. Some people, however, prefer such meats as fish, ham, and dried beef uncooked. Such meats should be free from disease germs. When fish and beef are preserved by drying, a larger part of the nourishing material of the meat is kept than when such meats are cooked and preserved. For this reason some people prefer to eat these without cooking, since both the flavor and quality are different from those of cooked meats.

The materials and the methods used in preparing foods have changed greatly since colonial days in the United

States (Fig. 240). Also, the diet of the American people has changed greatly during the last ten years. More fresh fruits and vegetables and less meat are being eaten. Salads of raw vegetables and fruits, besides serving several valuable purposes in the diet (see page 443), add much to the pleasure of eating if they are skillfully prepared and attractively served. The cooking of foods demands skill and care if it is to serve its purposes (1) of improving the flavor, (2) of making tough meats and coarse-fibered vegetables more easily digested by softening their tissues, and (3) of killing harmful parasites and germs which often find their way into foods. The best diet includes both raw and cooked foods.

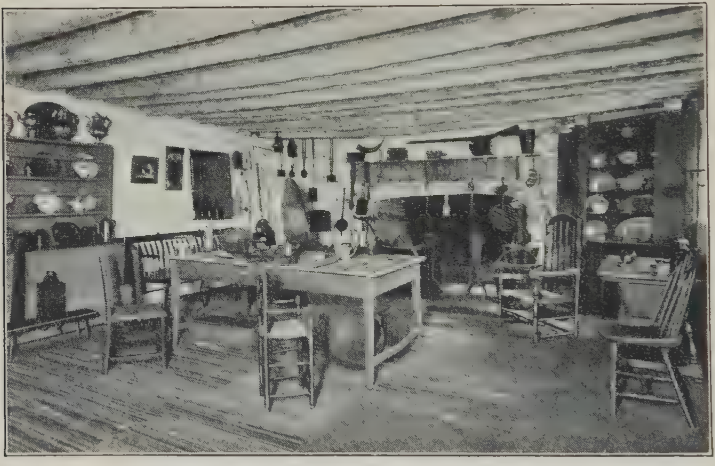

FIG. 240. THE KITCHEN IN THE VAN CORTLANDT MANSION, NEW YORK CITY

This kitchen has been restored so as to look as it did in the days of the Revolution. All the cooking was done in the great fireplace. (Photograph by Frederick Bradley)

The cooking of foods makes up the greater part of certain studies and is a special subject in which you may later have the opportunity of engaging.

Special Reports. Prepare a list of twenty of the most common foods used in your home. After discussion with your parents, compute the average cost per person in your family for food for a year.

Special Reports. Prepare a list of five cooking utensils used in homes, each showing a different application of a principle of science. Prove which ones cook most efficiently. Compare methods of cooking in colonial and pioneer homes with those used today.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. A food which is rich in carbohydrates is **meat** **butter** **olive oil** **oranges** **eggs.**
2. A food rich in fats is **oranges** **potatoes** **rice** **lemons** **olive oil.**
3. A food rich in protein is **oranges** **potatoes** **milk** **olive oil** **watermelon.**
4. People who do hard work need larger quantities of **fats** **protein** **starch** **sugar** **carbohydrates** than people who do light work.
5. The foods necessary to growth are those which contain **protein** **starch** **sugar** **carbohydrates** **fats.**
6. Green vegetables and fruits are of importance as foods because they contain vitamins.
7. When cereal is added to sausages the cereal is an ____.
8. Foods are preserved by ____ them, ____ them, ____ them, by adding ____ to them, and by keeping them at a low ____.
9. A proper diet should contain both cooked and raw foods.

CHAPTER XXVI

THE HUMAN MACHINE

Some Questions this Chapter Answers

How can one start his own body in motion, cause it to run, and make it stop? Can one make his heart beat as he wishes or stop it from beating? What is the human skeleton? How do the bones and muscles act when the arm lifts a load? How does the blood circulate? How should cuts and bruises be cared for? What is the digestive system? What are the special uses of the lungs? of the kidneys? of the skin? What is the relation of breathing to respiration? What is carbon dioxide? carbon monoxide? What is meant by the "hygiene of the digestive system"? What is the nature and use of the nervous system? What are the nature, use, and proper care of the special sense organs?

290. What the body can do. In running a hundred-yard race the runner starts himself quickly, drives himself over the whole course, and stops himself in a few feet after the finish of the race. He can control his starting machinery. He can adjust himself into high or low speed. He can go in the reverse direction if he wishes. Or a human body under its own control may climb a tall tree or a tall building and may move about among the limbs of the tree or over the frame of the building. In a circus we see human beings bend themselves into positions that seem almost impossible, and throw themselves about in a way that seems to be extremely careless, but is not. The fingers may be trained to move over the piano keys with great accuracy and with such speed that the eye cannot follow their movements. The human body can be placed by its owner in an airplane, and for thirty hours and more can hold a charted course in the air without rest, almost without food, and without companions. How can a machine possess its own moving power and be its own guide? How can it move itself with the speed of the runner, or with the accuracy of the one who plays the piano, or with the skill and ability to endure which are demanded of the aviator?

While the actions just referred to and many others are going on, many other things are done by the body without the owner's noticing that they occur. When you wish to move your hand, do you think about it first, then decide that you will move it, and then raise it and place it where you wish it to be? Or do you decide to use your hand in doing some work and put it to the task at once without knowing just how it is moved? When you are walking do you decide, "Now I'll lift this foot" and "Now I'll lift the other foot," or can you walk along and talk with a friend without thinking about how you walk? Do you breathe without attending to it? Do you direct the beating of your heart?

The things our bodies do under our direction are called voluntary[1]; the things we do not direct are called involuntary.[2]

291. What holds us up? You may have watched as a building was being put up and have seen the frame that is first erected. It may be pieces of steel or heavy pieces of wood, but it stands in the air as a sort of outline of the whole building that will later appear. Such a frame is called a skeleton.[1] No building can be of much use if it has only a skeleton, but no working building could be made without some sort of skeleton.

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[1] *Voluntary* (vol′un ta ry): as one wishes, or acting of one's own accord.

[2] *Involuntary* (in vol′un ta ry): without control, or acting without planning or without being guided.

*The bones compose the human skeleton (Fig. 241). There are from two hundred four of these bones to two hundred eight, depending on whether some of the smaller ones grow together. The bones are so arranged that they can work together without being solidly grown together. The places where they are joined are called joints. Thus, on the skeleton shown in the figure, one can easily see the joints at the wrist, elbow, shoulder, hip, knee, and ankle. The bones of the neck and back have a joint between each pair of bones, and this makes it possible to bend and twist the neck and back. The many bones of the wrists and hands and of the feet and ankles have joints which allow great flexibility.[2] The arm below the elbow, the leg below the knee, each has two long bones so arranged with joints that they can turn part way round one another as well as forward and back.

Experiment 49. Can the elbow bones roll over one another? Sitting at a table, place your hands with the backs upward on the table. Have the elbows also resting on the table. Without raising the elbows from the table see if you can turn your hands over so that the backs are on the table. What bones and joints make this movement possible?

Experiment 50. How can you place your hand in the middle of your back? Standing straight up (that is, erect),

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[1] *Skeleton* (skel′e tun): the supporting frame of a building or of an animal body.

[2] *Flexibility* (flex′i bil′i ty): the ability to bend readily without breaking; the quality of being flexible.

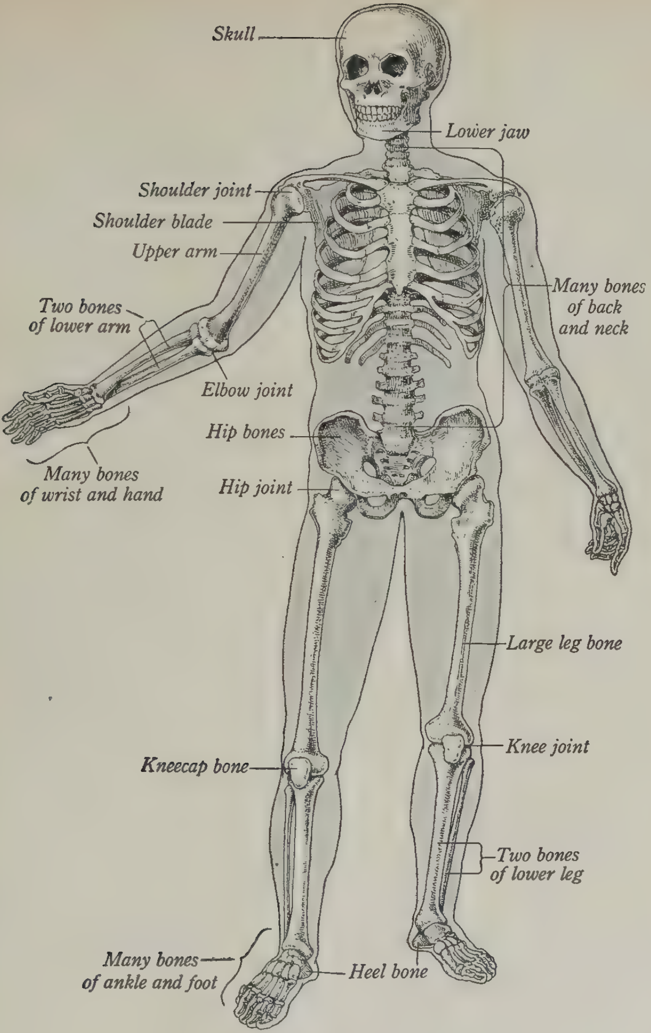

FIG. 241. THE HUMAN SKELETON

The bones are given their common names, but you can find the scientific names in library books on human physiology see if you can put first one hand and then the other behind you and with its back between your shoulders. What bones and joints make this movement possible?

Experiment 51. How much movement is possible for the lower jawbone? Can you move your lower jawbone upward and outward, backward and forward, and sidewise? What bones and joints make this movement possible?

292. *How bones are joined. If we observe the joints at the hip and shoulder in the figure and those at the elbow and knee, it becomes clear that they are not alike. If we hold one hand on the shoulder as the whole arm is moved in different directions, and then on the elbow as the lower part of the arm is moved, we can discover differences in the ways in which these joints work. The elbow and knee joints move back and forward only, like the hinges of a door. These are called *hinge joints*. The shoulder and hip joints are made so that the ball-shaped end of one bone fits into a hollow place (that is, a *socket*) of the other bone. This is called a *ball-and-socket joint*. Such a joint permits motion in many directions. We can understand the importance to us of this arrangement if we will experiment for a while in trying to use the shoulder and hip joints as if they were hinge joints.

The small bones of the hands and feet have joints of the ball-and-socket type; but the bones are small, and some of them are fastened together so that not much motion is possible. This type of joint does, however, make possible the movements in many directions upon which the work of hands and feet depend.

*The bones of the face and skull, except the lower jawbone and the bones within the ear (Fig. 242), are fastened together by joints which have very little or no movement.

The edges of the skull bones fit into one another as the teeth of two saws might fit together. Such a joint is called a *suture*.[1] In children these joints may allow a little movement, but in older people no movement in them is possible. In fact, babies do not have all the bones joined at the tops of their heads until they are one or two years old.

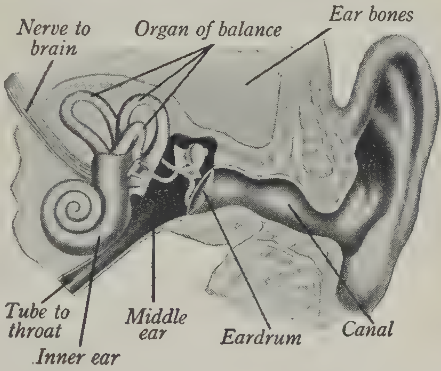

FIG. 242. DIAGRAM OF THE HUMAN EAR

Note that the organ of balance, which tells us when we are "right-side up," is in the ear

293. Muscles make the body move. *Experiment 52.* How do the arm muscles act when the hand picks up a weight? Place the arm flat on the table as shown in Fig. 243. Lift a weight as shown in the figure and, by watching the action of the muscles of your arm, see if all the actions shown in the figure can be traced in your own arm and hand. In this experiment it is possible also to note the changes in the muscles as the hand moves. What are these changes?

Experiment 53. Is there a change in the distance round your arm as it lifts a load? With the arm lying loosely on the table, make a tape-line measurement of the inches round the upper arm about halfway between the shoulder and the elbow and about halfway between the elbow and the wrist. Then lift the weight with the elbow bent at a right angle or nearly so, and with the whole arm free from the table. Now take the measurements again in the same places. What differences do you find? How can you explain these differences?

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[1] *Suture* (su′choor): joint formed by bones fitted together like the teeth of two saws or like the wooden edges of a dresser drawer.

The arms and legs are supplied with long muscles, which are attached by their strong ends, or *tendons*, to the ends of the bones. For example, in the upper arm the largest muscle on the front of the arm is attached at its lower end to the lower arm just below the elbow; at its upper end it is attached to the upper arm bone and to the shoulder bone. When this muscle becomes shorter, as occurs when it is lifting a load, the bone of the upper arm serves as a lever (see page 134), the elbow serves as a fulcrum, and the load on the lower arm and hand is lifted. The contracting of this muscle and others which work at the same time is what lifts the load. In the arms and legs one set of muscles pulls the feet or hands, or performs other tasks; another set is paired with these and pulls the feet or hands back into place again. No wonder boys and girls take pride in their good muscles, for these mean the ability to make the body work.

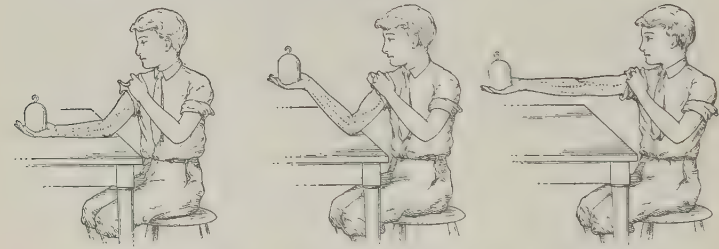

FIG. 243. HOW BONES AND MUSCLES WORK TOGETHER

Note that the arm is a lever of the same type as the fishing pole (Fig. 78, p. 135): the elbow is the fulcrum, the weight is the resistance, and the muscle applies the force. One muscle pulls the arm up and another straightens it out. Can you tell which muscle in each case?

*All over the body are muscles, — some long and slender, some round and shaped like a cylinder, and some flat and thin. All these muscles work by contracting in ways somewhat like those shown in the diagram. There are so many body muscles, and they do so many kinds of work in different parts of the body, that only a detailed study of their anatomy[1] could give us more than general information about them. The muscles, together with fatty[2] tissues, cover the skeleton of the body, and over all this is the skin. The skeleton gives support and serves as the solid but movable part on which the muscles do their work. The muscles not only do the work of moving the body or its parts, but they, with fatty tissues and the covering skin, give form to the parts of the body.

294. The heart the most important pump in the world. It seems strange to us that human beings did not know until a little over three hundred years ago that the blood circulates through the body and is kept moving by the heart. It seems even more strange that when William Harvey, an Englishman, announced his discovery that the blood circulates, most people did not believe it, and some prominent people said very unkind things about Harvey because of his announced discoveries. People sometimes have strange attitudes toward new knowledge. Everyone of any considerable education now knows that the blood circulates and that the heart pumps it.

Experiment 54. How can you tell how often your heart pumps, or beats, and how can you change its rate of beating? By placing the first finger of one hand across the wrist of the other hand, or by placing a first finger tightly against the neck just back of the lower jawbone, you can feel the flow of the blood as it is sent from the heart. It does not flow evenly, but seems to flow, then stop, flow, then stop, and so on, in what are called *pulses* or *pulsations*. Count the number of heartbeats, or pulsations, in one minute. Make a record of the pulses of five pupils; then have these pupils run or walk rapidly round a block or a similar distance elsewhere and return to the classroom. Take their pulses again and make a record of these. What differences are there? How can you explain these differences?

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[1] *Anatomy* (an at′o my): the study of details of structure of plants and animals.

[2] *Fatty* (fat′ty): composed of fat.

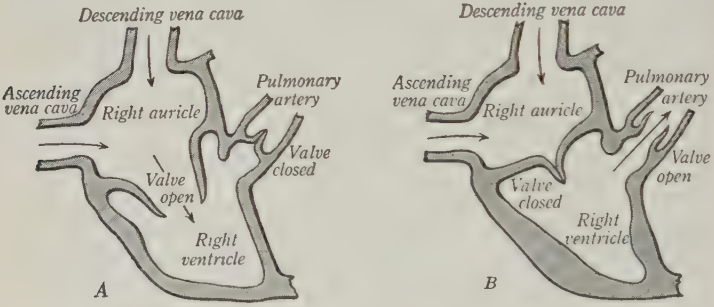

FIG. 244. DIAGRAM OF PARTS OF THE HEART

Can you explain how the valves are opened and closed by comparing the positions of the valves in *A* and *B* of the figure?

†The blood is pumped from the heart into large heavy-walled tubes called *arteries*. The arteries divide and become smaller as they reach distant parts of the body. Finally the blood leaves the smallest arteries and goes into tiny hairlike tubes called *capillaries*. In an earlier chapter capillary tubes were discussed (see page 354). The capillaries into which the blood goes branch into and from one another, forming a network.[1] They are in close contact with all the living cells in the body, so that

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[1] *Network* (net′work): a mass of threads running in all directions as in a net.

as the blood flows through them it is in contact with the living cells. The capillaries enlarge into small tubes much like small arteries, but they do not have heavy walls. These are called *veins*. Smaller veins join to form larger ones, and finally large veins lead back to the heart. The blood makes this round from the heart through the arteries, through the capillaries, through the veins, and back to the heart, only to start again on its circulation.

The heart is clearly a most important part of the body. A study of the diagram of the human heart showing the valves and muscles which drive the blood will give some understanding of this remarkable structure (Fig. 244).

Fill in the proper words in the following statement:

The blood is pumped throughout the body by the ____. The blood goes from the heart first into the ____, then into the ____, then into the ____, and back to the ____.

Special Report. Learn all you can about William Harvey and his work, and present a class report based upon what you learn.

295. *Bleeding from cuts and bruises. When the heart and all the blood vessels are working properly, blood is constantly carried to all parts of the body. When a part of the body is bruised, the capillaries or even the veins and arteries may be broken. In such cases blood passes out of the blood vessels through the breaks and lodges among the tissues of the body. Its dark color soon produces the blue or black place called the bruise. If the blood vessels heal quickly, the escaped blood may be absorbed and carried away and the dark spot will disappear. When more serious bruises occur, new blood vessels and tissues are built up below or about the injured area, and the damaged tissue is slowly replaced or worn away.

*When a part of the body is cut, the blood flows from the injured blood vessels. If only capillaries are cut, or even small veins, the blood flows slowly. If an artery is cut, the pulsations of the heart cause the blood to flow more rapidly. It is clear that there is more danger from loss of blood from cut arteries than from cut veins and capillaries.

When blood is exposed to the air, its solid parts join together and separate from the liquid part, and it is said to *coagulate*.[1] If the blood coagulates in the cut, it closes the wound and stops the bleeding. When an artery is cut, the pulses of the heart may keep the blood from coagulating in the wound. In such a case a cloth or a cord tied tightly near the cut and on the side nearest to the heart may stop or reduce the flow of blood and permit it to coagulate in the wound, though there is danger if the circulation of blood is shut off by the cord for longer than ten or fifteen minutes. Two apparently but not really opposing facts must be kept in mind: (1) It is important when cuts or bruises occur that the blood flow should not be excessive, for loss of too much blood causes death. Some flow of blood is desirable, since this helps to carry out any disease germs which may have got into the wound. (2) Then, after the wound is safely closed, good circulation in the tissues about it is essential to the processes of replacing and recovery.

296. †Keeping up the body's supply of energy. The human body will not run by itself for a very long time. The muscles will work for only a short time without a new supply of energy. This energy must be fed into the muscles through the capillaries from the blood. The heart does not supply energy to the blood; in fact, the heart itself gets tired and its muscles lose the ability to keep working unless the living cells of the heart's muscles get new supplies of energy from their own capillary blood supply. The blood secures new supplies of energy in all parts of the body from the oxidation of digested food. The oxygen is carried from the lungs and the food from the digestive system.

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[1] *Coagulate* (ko ag′u late): to become like a jelly or half-solid substance.

*The digestive system consists of all the parts which have anything to do with the body's preparation of food for use. Food is forgotten by most people once they have placed it in the mouth and have enjoyed its pleasing taste and presence. But the mouth is more than a convenient doorway through which to put food into the body. Digestion begins in the mouth. The jaws are provided with teeth for breaking and crushing the food into small pieces. The mouth has special organs called *glands*[1] which produce digestive juices called *saliva* (see page 443). The circulating blood does not carry starch, but it can carry solutions of sugar. It is important to give the mouth time to do its part toward the preparation of food; that is, to make chewing thorough in order that the saliva may do its work. It used to be thought that the drinking of water while eating interferes with the action of saliva, but this seems unproved. Excessive drinking during meals undoubtedly dilutes the digestive liquids.

*From the mouth the food goes to the stomach by way of a special tube called the *esophagus*. In the stomach other digestive processes are carried on by the action of digestive juices which are produced by glands in the walls of the stomach. It is interesting to know that weak hydrochloric acid is secreted by the stomach. This helps digestion by breaking up fatty substances, such as the fat particles in milk. The stomach has a regular motion which turns and mixes the food, thus helping to make it into liquid form. From the stomach food passes into the small intestine. Just as the food enters the small intestine other digestive juices formed by the glands in that part of the body are emptied into the intestine. These continue the process of digestion. From the small intestine any remaining food passes into the large intestine, where unused food and waste matter gather till they are sent out of the body.

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[1] *Gland:* an organ for making a special kind of body fluid.

†All through the linings of the stomach and small intestine there are folds of the tissue in the walls of which are millions of capillaries. Food is absorbed into these capillaries. From the capillaries the digested food goes through the veins to the heart and is pumped throughout the body. When living protoplasm needs food it takes it from the blood in the capillaries.

†There are also millions of capillaries in the walls of the lung cells. In the blood are red bodies known as corpuscles.[1] The red color is due to a material called hæmoglobin.[2] The hæmoglobin combines with oxygen in the capillaries of the lung cells. In the lung cells the carbon dioxide of the blood passes into the air within the lungs, and the carbon dioxide is then breathed out through the nose and mouth. The renewed blood passes back to the heart and is sent over the body again. In the capillaries in the body cells the oxygen is used from the hæmoglobin. It combines with the protoplasm (see page 442), releasing the energy of the protoplasm. At the same time the products of broken-down protoplasm, among which are carbon dioxide and compounds of such elements as nitrogen, phosphorus, and sulphur, are taken up by the blood. The

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[1] *Corpuscle* (kor′pus el): a very small body in the blood. There are red corpuscles and white corpuscles.

[2] *Hæmoglobin* (hem′ o glo′ bin): the coloring material of the red blood corpuscles.

blood is later freed of these waste products, chiefly in the kidneys. The urine produced in the kidneys is a highly important means of disposing of waste products, which if not removed would poison the body.

†The proper care of the skin has much to do with good health. The skin helps by evaporating moisture from the blood and by relieving the blood of other wastes which pass to the surface of the skin. Regular bathing helps to keep the skin in condition to do its work.

297. ***Breathing and respiration.** Breathing refers to the act of taking air into the lungs and sending it out through the nose and mouth; in other words, breathing deals with getting air into and out of the lungs. Respiration includes breathing and it also includes the changes of gases between the air and the blood both in the lungs and in the other body cells. Respiration deals with the taking up of oxygen by hæmoglobin, with combining oxygen with the living protoplasm, and with the transfer of carbon dioxide from used protoplasm to the blood and its later transfer to the air in the lungs. Breathing is sometimes spoken of as external respiration. By internal respiration we mean the important chemical changes within the tissues and blood.

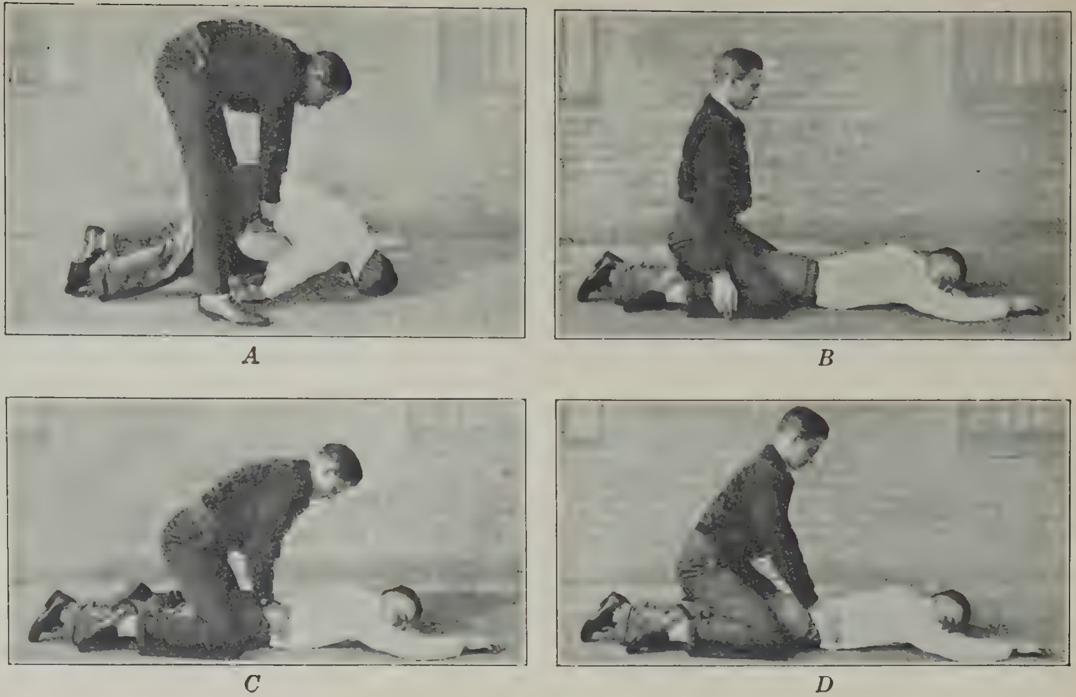
298. ***Accidents to the body.** The most common types of accidents are cuts and burns. If no pieces of foreign material, such as glass or dirt, are left in the wound it may be treated at once. A soft-cloth bandage saturated with a dilute salt solution is best for cuts. Use one teaspoonful of salt to a pint of water. By osmosis (see page 353) the salt extracts the moisture out of any bacteria that may be present and kills the bacteria. Osmosis also causes free bleeding, and this cleanses the wound. If a wound has become infected or has foreign substances in it, washing it thoroughly with a salt solution is helpful. It is important

that a wound should be kept clean and properly bandaged until nature has had a chance to replace the injured tissue. In healthy people such wounds will quickly heal when no infection has been allowed to get started. Nearly all cases of serious difficulty from cuts are due to neglect during the first day or two. In very bad cases a physician should always be called.

*It is not uncommon for children to break bones in playing or in falls or in automobile accidents. The first necessary action is to get the injured person out of further danger; the second is to call a physician. In moving a person who has a broken bone, great care must be taken not to bend or twist the body into unnatural positions. This may usually be accomplished by slipping a blanket under his body, then carrying him upon the blanket to a place of safety to await the physician's arrival.

*Accidents by drowning and gas-poisoning (see page 204) are usually more serious than are cuts, burns, and breaks. The chief dangers from gas-poisoning are from escaping coal gas or lighting gas and from carbon monoxide gas. In gas-poisoning the carbon monoxide combines with the hæmoglobin of the blood and thus prevents the blood from carrying oxygen. The first thing to do in a case of gas-poisoning is to get the patient into fresh air; the next is to call a physician. Start artificial respiration as in the second, third, and fourth parts of Fig. 245, and continue the efforts until the arrival of a physician or until the patient breathes of his own accord.

*Drowning also requires very prompt action. Artificial respiration should be started as soon as possible. Figure 245, *A*, shows how to handle the patient so as to clear the upper air passages of water. Then place the patient as shown in *B*, and place your hands as shown in the figure.



A B C D

FIG. 245. HOW TO CARE FOR A CASE OF DROWNING

Then with your own body in the position shown in *C*, and with your weight partly thrown upon your hands, force the air out of the patient's lungs. Immediately take the position shown in *D*, and wait two seconds for the patient's lungs to fill with air. Then repeat these operations until natural breathing is started.

When the patient revives keep him lying *on his face* until breathing is easy and normal. Do not turn him over on his back. When he is out of danger he will turn over of his own accord.

> *Special Report.* Secure the assistance of a Boy Scout or Girl Scout leader and prepare a class demonstration and discussion of first aid (1) in cases of drowning and (2) in cases when people are overcome by gas.

299. †Hygiene of the digestive system. Many persons have ill health because they do not realize that most of our bodily troubles come by way of the digestive system. When we put into the digestive system more food than it can use or a kind that it cannot use, trouble must follow. We might laugh at the man who crowded his furnace with so much coal that the fire was choked from lack of air. Half the coal would have produced a better fire than all of it could possibly produce; in fact, all of it produced no fire. Yet some people will crowd into their stomachs such an amount of food as to prevent proper digestion of any of it. Then, too, irregular habits of putting in food or clearing away the wastes do not permit a digestive system to work well. Regular habits of eating and of disposing of wastes are necessary for good health.

Most people now have "the toothbrush habit" so well formed that they are not comfortable when they fail to use the brush. Tooth pastes are helpful for use part of the time, but most of the time a good clean brush well used each day will be superior to an infrequent scrubbing with a tooth paste. Acid tooth pastes (see page 116) should be avoided, since they injure the gums and may injure the hard surface of the teeth.

†Most drugs and patent medicines should be avoided. These are sold most extensively in regions where there is least education and greatest poverty. This relation is not an accident, for there is a reason. Why are patent medicines bought mostly by the very poor and the ignorant?

> *Special Report.* Secure the bulletins on patent medicines published by the American Medical Association. From these prepare class discussions of the dangers in using many well-advertised patent medicines and healing devices.

*Vigorous good health is almost certain to follow if these rules are observed: (1) eat only good food in proper amounts; (2) keep the digestive system free from disease germs; (3) remove body wastes regularly; (4) breathe plenty of fresh air and see that the ventilation of your home is good; (5) take regular exercise.

300. †How we know and do the things that we know and do. A human body would not be of much use if it could do no more than be supported by its skeleton, move about by use of its muscles, have its blood circulate, exchange good and bad air by breathing, and digest and assimilate food. All through the body there is a system of special cells called nerve cells by means of which we find out all we know about what occurs in our bodies and all we know about the world outside ourselves. These nerve cells are organized either into threadlike bodies called nerve fibers or nerves, or into partly rounded masses called nerve centers. The nerve fibers connect directly with the nerve centers; indeed, the nerve fibers grow outward from the nerve center. The nerves run to all parts of the body. Also all the nerve centers are connected by nerves which run toward the larger centers. The largest nerve center is in the skull and is called the brain. Other large nerve centers are at the base of the brain and in the hollows of the vertebræ of the back. There are smaller nerve centers in various parts of the body.

†Most of the nerves which extend farthest from the main nerve centers end in such parts as the muscles, the skin, the digestive system; but some nerves run to special parts of the body for special kinds of work. The touch cells in the finger and elsewhere are the ends of nerves which enable us to use the sense of touch. The eye (Fig. 341, p. 622) with its nerves enables us to use the sense of sight, the ear (Fig. 242, p. 463) enables us to hear, the nose enables us to smell, and the tongue has special nerve structures by means of which the sense of taste operates. These are commonly known as the special sense organs. Their importance in relation to our learning of what is going on about us can hardly be overestimated. Helen Keller, who can neither see nor hear, has risen above these great disadvantages. She reads, speaks, enjoys life, and is helpful to other human beings. Try to imagine yourself deprived of one of these special senses, then of another, and guess how you might undertake to learn without them.

Special Report. Read the life of Helen Keller, and describe how she has used the senses she possesses to make up for those she does not have.

†A little attention will show you that your nervous system attends to a good many things without your really knowing it. When you first tried to walk or catch a ball,

your feet and hands did not act very promptly or very well. You gave them all your attention. Now you may walk or run or catch a ball and give most of your attention or all of it to something else. In the same way you no longer delay in removing a hand from contact with an object which might burn it. The nerve centers below the brain have been trained to direct the action of the muscles without waiting for the brain to attend to it; that is, the first response that comes over a nerve is turned back into action immediately by one of the nerve centers in the backbone. This kind of action which requires no thinking is called *reflex*. In reality this kind of reflex is a habit. *Habits* are things that have been done so often that the reflex nerve centers take care of them whether the brain gives them attention or not. It is very important to get as many good habits as possible so that the body may work well and the brain be left free to attend to important things which cannot be habits or at least have not yet become so. Of course the nerve centers act in the same way with harmful habits as with helpful ones. Habits which we have inherited from our parents without ever learning them are called *instincts*.

301. The proper care of the special sense organs. What would you accept in exchange for your eyes? your ears? Some people act as if they do not understand how much these and the other special sense organs are worth to them. A boy who dares another to look straight into the sun may have good eyes now, but he has not made good use of his brain and may not have good eyes very long. One who reads with light shining into his eyes needs to do some thinking (Fig. 344, p. 625).

One who does not sleep enough to give adequate rest to his nervous system as well as to all of his body cannot reasonably ask his sense organs to go on doing their part for him. Sleep and nourishment enable the body to clear out its wastes and to gain new energy. Without these we are asking our bodies to do what soon becomes impossible.

†The special study of the organs of the body and how they work is called human *physiology*. The special study of the proper care of the body to keep it always in good health is called *hygiene*. The special study of how we use the nervous system in thinking and acting is called *psychology*. Possibly in your later studies you may have a chance to study further in each of these fields and to learn more about the control of the body.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. In the complete human skeleton there are **104** **208** **32** **410** **57** bones.
2. Three types of joints are ____, ____, and ____.
3. The body is moved by the action of ____.
4. The blood is caused to circulate through the body by the action of the ____.
5. Bruised places look black or blue because blood has escaped from the blood vessels into the bruised area.
6. When blood flows rapidly in pulses from a wound, it is a sign that a vein has been cut.
7. Wounds should be allowed to bleed a little.
8. Glands in the mouth furnish saliva, which digests fats.
9. Hydrochloric acid in the stomach digests starch.
10. Oxygen is carried to all parts of the body by the blood.

SCIENTIFIC PUZZLES AND GAMES

Which of the five statements that follow each of the two problems stated here would a carefully trained scientist choose as best? Justify your answer by stating one or more of the scientific attitudes (see pages 8–10).

Problem 1. Eleanor beat Helen two straight sets of tennis, and therefore we conclude that Eleanor is the better player of the two.

a. The conclusion is probably sound, but might not be.
b. There is no doubt that the conclusion is sound.
c. The conclusion is almost certain to be sound.
d. The conclusion is probably unsound, but might be sound.
e. The conclusion is unsound.

Problem 2. A man of long years of experience made the statement that three horse chestnuts carried in one's pocket will cure rheumatism.

a. This belief is probably sound because "three is a charm."
b. The belief is probably unsound because the cures thought to be due to carrying horse chestnuts are most likely to have been caused by something else.
c. The belief is probably sound because horse chestnuts are likely to contain a kind of medicine which can pass through the clothing into a person's body.
d. The belief is sound because I have heard of people who were cured of rheumatism in this way.
e. If I should have rheumatism I would surely give this remedy a trial.

UNIT XI. FOREST, FARM, AND GARDEN

CHAPTER XXVII

TREES AND FORESTS

Some Questions this Chapter Answers

How do evergreen and deciduous trees differ? What was the original extent of forests in this country? How are forests related to moisture? to the flow of streams? How do forests affect floods? How do forests affect the nature of soils? What is meant by "respiration"? What are the important steps in transplanting a tree? What is self-pruning? How may trees be protected in parks and city streets? What is being done to insure a future supply of timber? What are memorial trees?

302. †The life of a tree. A tree consists of roots, stem and branches, leaves, flowers, and seeds. These parts carry on their work in much the same way as in other plants (Chapter XXI). The roots, stem, and branches continue to live and keep getting larger and longer for many years. In some kinds of trees the leaves also continue to live for several years. Such trees are known as evergreens.[1] Examples of evergreen trees are pines, spruces, and cedars.

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[1] *Evergreen* (ev′er green): a plant that always has green leaves.

Trees that shed all their leaves at the close of the growing season are called deciduous.[1] Oaks, maples, and most of our common trees are deciduous. The leaves of an evergreen tree do not remain on the tree throughout its life. They rarely remain more than four years, and usually fall off when they are about two years old. The leaves of evergreen trees are falling over a long period of time, sometimes for three or four months. The leaves of deciduous trees fall in large numbers in a few weeks, sometimes in but a few days in the late autumn. Evergreen leaves are narrow and hard or stiff; deciduous leaves are broad and usually thin. Evergreen leaves do not expose much chlorophyll to the sunshine, but are ready to work producing food whenever the weather is favorable. Deciduous leaves expose broad chlorophyll surfaces to sunshine, then drop off, and the tree has no leaves and consequently can make no more food until a new crop is produced the next year.

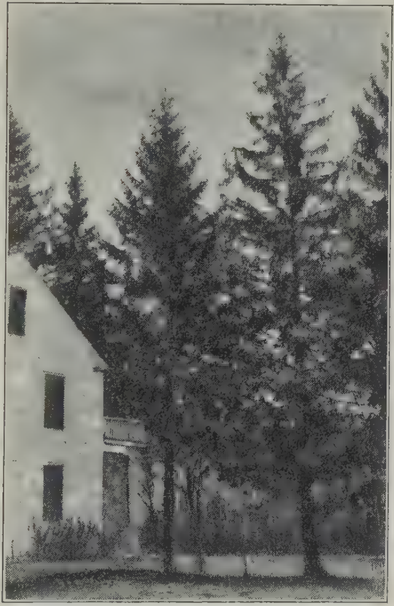

FIG. 246. WHITE SPRUCE TREES

The lower branches are longer than the upper ones. Standing almost at right angles to the main body of the tree, all the branches together produce a conical tree form

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[1] *Deciduous* (de sid′u us): shedding all its leaves at regular times.

†Whether evergreen or deciduous, the leaves of trees manufacture the food by means of which the tree grows and produces its flowers and seeds. These two types of trees have different shapes which are related to the ways in which the leaves secure sunlight. The stem and branches of most evergreens are in the form of a cone, the lower branches being longer than the upper and extending outward from the main stem (Fig. 246). Most deciduous trees have large spreading branches (Fig. 247). Individual trees have many kinds of variations from these typical forms.

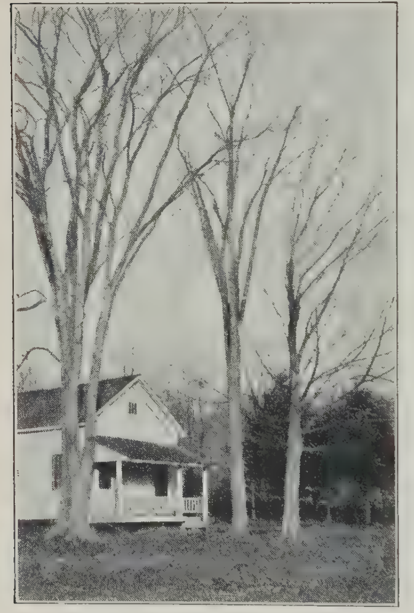

FIG. 247. THE SPREADING BRANCHES OF THE ELM TREE

This arrangement makes it possible for the leaves when they are on the tree to receive light. The smallest of the three trees is a sugar maple. Note how some of its branches have turned away from the elm because they were shaded by the elm

†The main part of the stem and branches is made up of woody tissue. Almost all this woody tissue is dead, the only living wood being on the outside just beneath the bark. A new layer of woody tissue is made each growing season, and new bark is produced beneath the old bark. In this way the stem and branches are getting thicker each year by means of the yearly, or annual,

growth rings of wood. By counting the growth rings of a tree, its age can be fairly accurately learned (Fig. 248).

In general, the deciduous trees have harder wood than do the evergreens. It has become common to speak of deciduous timber as hard wood and of evergreen timber as soft wood. Some timber from deciduous trees, however, is softer than some of the harder evergreen timber.

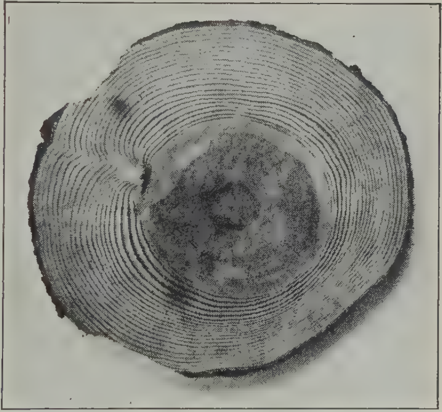

FIG. 248. CROSS SECTION OF A PINE TREE

In the earlier years of this tree's life it was crowded by other trees and its supply of light was not nearly enough. During these years the growth rings were so close together that they cannot be made out in the picture. Then all the larger timber was cut away, allowing abundant light for this tree. How many years did the tree live under favorable lighting? (Photograph by the United States Forest Service)

Trees, like other plants, have many different kinds of flowers and seeds. There are the long flowers of the cottonwood and hickory, the colored flowers of the tulip and magnolia, and the almost hidden flowers of the beech. The seeds of the walnut, the hickory, and the oak are known to everybody, though but few have watched these seeds grow into new trees.

Project. To collect as many kinds of tree seeds as you can find and to prepare a class exhibit of them. Plant some of the seeds under leaves and upon moist earth and see if you can start new trees from the seeds.

Experiment 55. How can you learn the age of a branch of a tree? Bring to the classroom a number of branches of cottonwood or hickory. By observing the surface of a branch or twig locate the scars where the different years' growth began, and see how many years old the twig is.

FIG. 249. A PACIFIC COAST LOADING DOCK WITH LUMBER FROM WASHINGTON AND OREGON BEING LOADED FOR NORTH ATLANTIC PORTS

Photograph by Ewing Galloway

Cut across the oldest part and see if its growth rings show the same age as did your count of the growth scars.

303. *The value of trees and forests. In early times in this country there were very large areas of both deciduous and evergreen forests. As the trees were crowded together and had to reach for light, their stems had grown tall and straight and thus were of the best kind for making lumber. Almost half the land of the United States, or an estimated area of 822,000,000 acres, was originally covered by forests. There are now about 138,000,000 acres of native forests. In addition to this there are large areas of cut-over forest lands and a considerable area of planted forests. When farming began, there was greater need for the land for farms than for the timber, and much of this valuable timber had to be burned. Those who cleared the land had to destroy timber, and the destruction went so far that the original forests were almost all used for lumber or burned. Lumber is now shipped across the United States from the forests of the Northwest to supply at least part of the needs of regions which have wasted and destroyed their own rich supplies of the finest forests (Figs. 249 and 250).

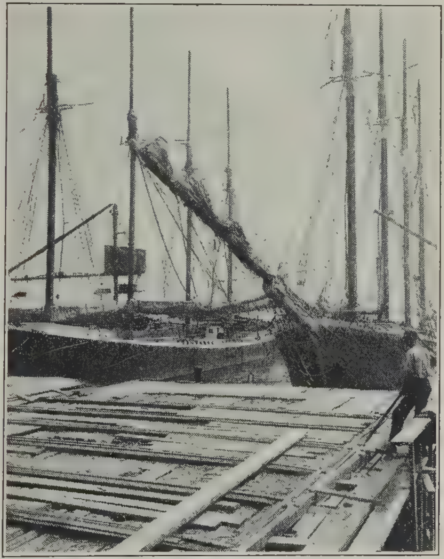

FIG. 250. PACIFIC COAST LUMBER BEING UNLOADED BY MOVING DOCKS IN NEW YORK HARBOR

†Fortunately people now more generally appreciate the beauty and value of trees and encourage their growth. Trees add to the beauty of homes and landscapes. They serve as homes for birds, and birds help to hold in check insects that would injure not only the trees but farm

and garden crops. The leaves and twigs of trees fall and produce a spongelike mass which as it decays produces the rich soil called *humus*. The humus absorbs and holds moisture in the soil. Since forests help to hold moisture in the soil, they help to regulate the flow of streams. If snows and rains are held by forests the water will run off less rapidly than from open fields, and floods are less likely. This regulating of moisture also helps to reduce to some extent the extremes of temperature. Anyone who has been in dense forests knows that they are cooler in summer and warmer in winter than the surrounding open country. Explain why this is so.

304. Forests and soil. The humus produced by trees is an important addition to the fertility [1] of the soil. When one digs into the humus in a dense forest, he finds first the leaves recently fallen, below these the partly decayed leaves of preceding years, and below these the rich soil in which the form and appearance of leaves is no longer to be seen. In all these layers one may see the molds (see page 380), mushrooms (see page 384), and small animal life living on the leaves and helping to reduce them to soil materials. In addition there are many bacteria (see page 385) and small animal organisms which cannot be seen.

†Forests are highly important as soil-makers. When walking in a forest during a heavy rain one may see that the falling water is soaked up by the humus. When the humus can absorb no more, the water flows away slowly toward the stream beds. The water does not carry much of the humus with it. Open fields absorb less of the water of a heavy rain, and there is less to hinder its flow; hence its flow is both larger in quantity and more rapid. Thus

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[1] *Fertility* (fer til'i ty): ability to produce new life or to aid the growth of plants.

water is able to carry more soil away from open fields than from forests (see page 306). In forests over which fires have gone the humus has usually been burned. In such regions erosion during heavy rains occurs as in open fields. Fire and water, both so necessary in human affairs, are both very destructive of soils when not controlled.

Trees may be planted in places where erosion of soils has been going on. If the trees get well started, their roots and later their leaves help to stop the erosion. The best kinds of trees to plant in such places are willows, cottonwoods, and black locusts. When the ground is not being eroded too rapidly, other kinds of trees which may later be more valuable for timber may be planted, such as ash, maple, walnut, oak, and hickory.

In this connection read again and discuss section 209, pp. 305–309, and note Figs. 176 and 177.

305. †Forests and floods. Water tends to run off more rapidly on areas where there are no trees, as has been shown in the preceding section and on page 306. It has also been shown that rapidly flowing water can carry large amounts of soil and other materials (see page 294). In the more level country, as the streams approach the oceans or lakes into which they empty, the water flows more slowly and deposits part of its load. This fills up the stream beds and may cause the streams to break over their banks into the surrounding country (Fig. 146, p. 238). When this occurs people, farm animals, and wild animals may be drowned, farm and garden crops may be destroyed, forests may be killed, and small vegetation may be smothered by a covering of fine soil. To prevent such damage, the banks of streams have been built high in the form of heavy walls called dikes or levees. The banks of the Mississippi River are thus protected for long distances by levees.

†Fig. 251 shows the area from which water flows into the Mississippi River from its branches. A study of this figure will help toward understanding how forests are related to flood control. A large part of the area drained by this river was once covered by forests. Most of it has now been cleared of forests; hence when heavy rains fall or when snows melt, the water runs off rapidly. The lower part of the river receives in a few days or a few weeks much of the water which would have come down more slowly over a period of several weeks or even months if the upper parts of the area drained by the river had still had their original forests.

†Reforestation[1] and care of the forests still remaining should help somewhat in controlling floods, but probably cannot prevent some future floods like those of recent years. The only immediate relief seems to be in building larger and better levees, in dredging the stream beds, and in planning certain regions of overflow in time of floods. The nation whose people have destroyed so much of the forests must now devote large sums of money toward preventing floods.

306. †Planting trees. Trees for planting are now usually secured from tree nurseries.[2] They may be secured from open forests, but those from nurseries are likely to be better for transplanting.[3] Interest in tree-planting has become so widespread that tree nurseries (Fig. 252) have developed in all important centers throughout the United States. The cost of trees is so low that they may be had by anyone who wishes to plant them.

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[1] *Reforestation* (re for′es ta′shun): planting forests again upon areas from which the forests have been removed.

[2] *Nursery* (nur′ser y): a place for caring for little children; also a place for raising young plants.

[3] *Transplant* (trans plant′): to plant again in another place.

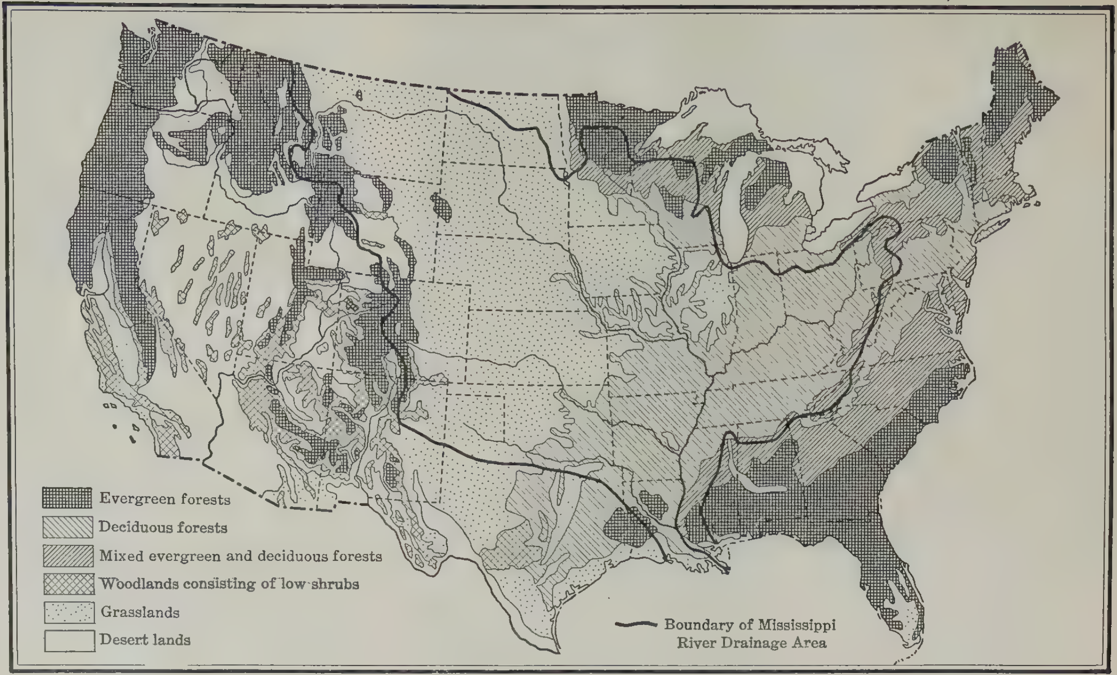
Evergreen forests
Deciduous forests
Mixed evergreen and deciduous forests
Woodlands consisting of low-shrubs
Grasslands
Desert lands
Boundary of Mississippi River Drainage Area

FIG. 251. THE MISSISSIPPI RIVER DRAINAGE AREA

†We must keep in mind that when a tree is transplanted its whole root system as well as the rest of its body is removed from its old home to a new one. This sudden change usually makes less difference to the stem and the leaves than to the roots. The roots are the parts which have grown into the old home, and it is the roots, thus established in the soil, which secure water and other materials for the work of stem and leaves. Hence disturbing the roots must affect the whole plant. It is often not possible to remove all the roots without injury. When the roots are placed in a new home, they must become adjusted and must produce new root hairs before they can work well again.

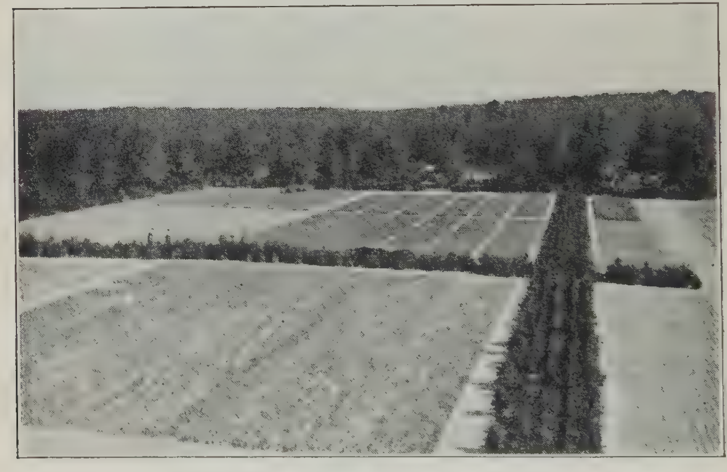

FIG. 252. A FOREST TREE NURSERY

Young trees of several kinds are shown in the garden-like plots. (Courtesy of the United States Forest Service)

†Leaves, and to some extent twigs and branches, evaporate water into the air. If water is not coming into the

plant through the roots in the amounts needed and is being evaporated from the upper parts of the plant, there is danger of too much drying and of the death of the plant.

†Deciduous trees can have part of their branches pruned, thus reducing the amount of the plant which the roots must supply with moisture. By the time new top branches and leaves have developed, the roots may have become well started in their new home and thus be able to provide abundant moisture for the rest of the plant. This pruning should also be so done as to help produce a good form for the plant (Fig. 253). It used to be said "Just as the twig is bent, the tree's inclined." It may now be said "As the young tree is pruned, so is the old tree inclined."

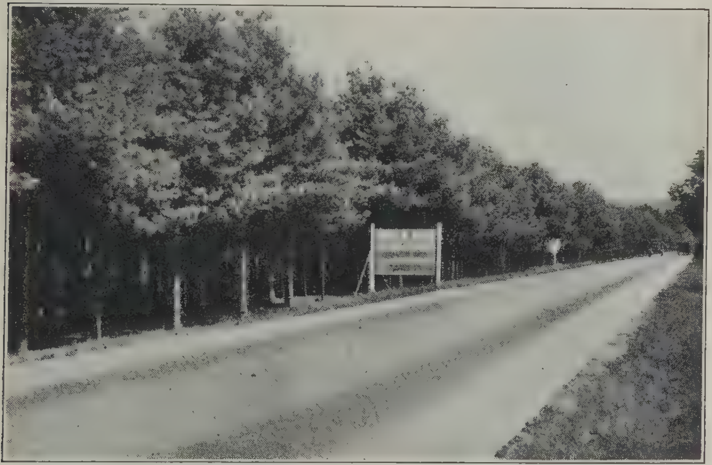

FIG. 253. A DENSELY PLANTED FOREST MAY PRUNE ITSELF

This white pine plantation is so arranged that the struggle to get light causes the trees to grow tall and straight, and the shading of lower limbs causes them to die. What differences are shown by this figure and Fig. 256? (Photograph by the United States Forest Service)

†The hole for the tree should be made deeper than the tree is to be placed and be partly filled with soft earth and humus. If humus is not available, barnyard manure should be thoroughly mixed with the soil below the position to be occupied by the roots. Place the plant in position with the roots carefully spread in all directions (Fig. 254); then sift soft earth over and among the roots until they are well covered. Press the soil gently but

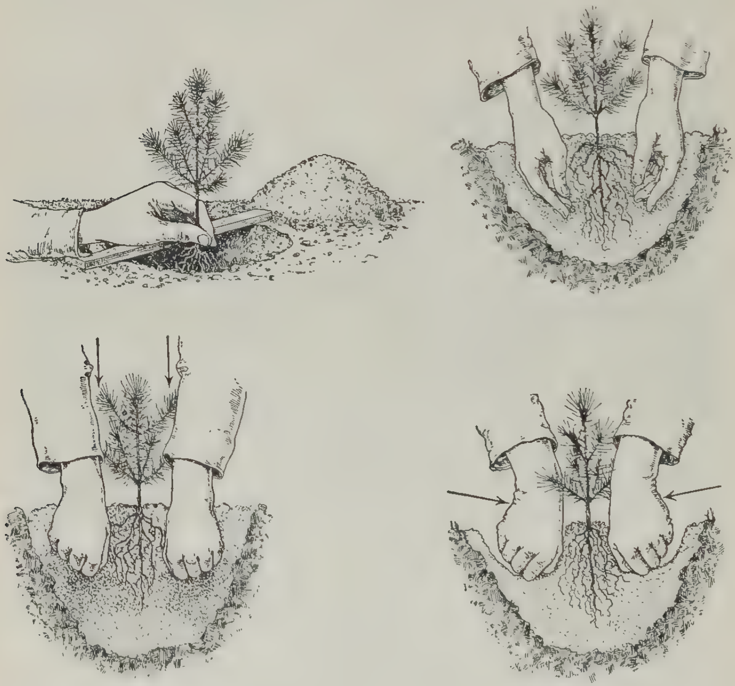

Fig. 254. Stages in Proper Tree Planting

Can you determine how the roots and soil are adjusted so as to insure proper distribution of the roots and proper soil relations?

firmly with the hands, pushing slightly toward the stem as well as downward so as not to pull or break the roots. Then water the roots thoroughly and place more soft soil above them. The whole mass of roots should stand a few inches deeper than in the plant's old home. If dry weather should follow, keep the trees well watered, thus making the roots able to get moisture while they are becoming established.

†Evergreen trees do not produce new branches and leaves in the same way as do deciduous trees. New growth comes on evergreen trees only at the ends of branches (Fig. 255). Therefore they cannot be pruned in the way recommended for deciduous trees. This also means that the roots of most evergreens must be handled differently when transplanted unless they are changed immediately from the old home to the new one. Usually young evergreen trees are removed from the ground by carefully digging entirely round the roots. Then the roots, with the soil about them, are lifted into a tub of very wet clay. The clay adheres to the roots and soil. The whole mass is then rolled and tied in rough

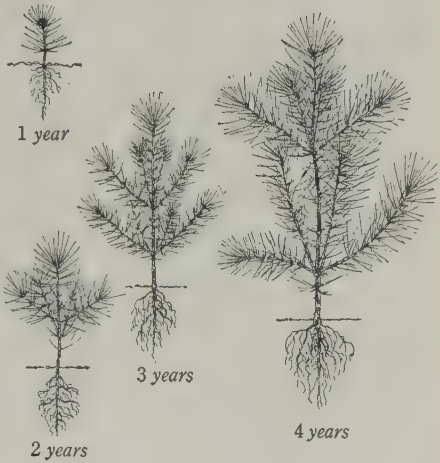

FIG. 255. YOUNG EVERGREEN TREES

The new growth appears at the ends of branches and at the end of the main stem. Compare the plants of different ages cloth. This process is called *puddling*. It holds the roots and soil and keeps them moist for a long time. This makes it possible to transport such trees long distances for planting. Young evergreens may be transplanted directly if the roots are not allowed to become dry.

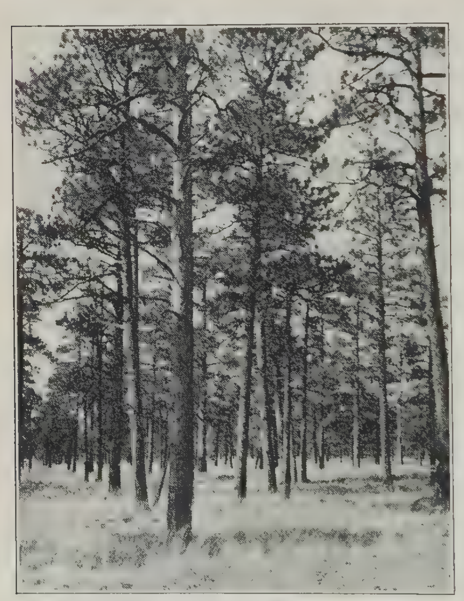

FIG. 256. THIS FOREST HAS PRUNED ITSELF

Western yellow pine, Coconino National Forest, Arizona. (Photograph by United States National Forest Service)

307. * How to arrange trees. Trees, planted for production of forests for timber, should be spaced from six to eight feet apart. This soon causes them to crowd one another and to reach upward for light. In a few years such plantings have become dense growths, the stems have become straight, and the lower branches have begun to die from lack of light. Self-pruning (Fig. 256) of the lower branches is an important feature of trees grown for timber. After several years trees may be removed; the spaces may be replanted[1] or left for the spreading of older trees. Indeed, continual use and replanting seems the only wise forest policy.

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[1] *Replant* (re plant′): to plant again or in the same place.

Special Report. Examine the inside of the top and outside of several shade trees when they have their leaves. Is there evidence as to whether leaves and twigs fail to live for lack of light? If two trees stand close together, how do the tops adjust themselves so as to secure light?

When planted for shade or decoration, each tree should be given plenty of space in which to produce a spreading top without becoming too high, for trees will not grow tall unless they must do so in order to secure light. Most cities now have laws prescribing where and how trees may be planted, and in many cities certain officials are responsible for such care as the trees may receive. That this care is not always given with a knowledge of what a tree is and what it needs is shown by the kind of care given or by the lack of care. For example, a tree's roots need air and moisture. But cement sidewalks and paved streets often almost completely cover the entire area in which the roots live (Fig. 197, p. 348). Why should we be surprised when the trees die? The wonder is that with such treatment they can continue to live for years. When trees are planted in cities they should be placed in parks and other open places where they may secure the things they live by.

Special Report. Make a diagram of some definite area about your school or home, show the individual trees or regions of trees, and describe the ways in which these trees are being cared for. What changes, if any, do you think should be made in their care?

308. *Protection of trees. In forests the chief danger to trees is from fires and lightning. No way is known of protecting forest trees against lightning. This, however, is a danger only to individual trees, except when lightning starts a forest fire, as often occurs. Many forest fires are thought to be caused by careless people who leave camp fires burning and who throw lighted cigars, cigarettes, or pipe tobacco and matches in places where fires may start. If such people could always be made to look at the fires they cause, to help fight them, and to repay, as far as they are able, those who suffer losses from them, there would be fewer forest fires.

The shade trees are attacked by destructive insects. If, however, birds are encouraged to nest in them, they pay their way not only by song and beauty but also by devouring the insects (see page 395). In cities the trees are sprayed with insect poisons. This helps to hold the insects in check. If it were possible to have birds enough to control the insects, it would not be necessary to use poisonous sprays to fight insects.

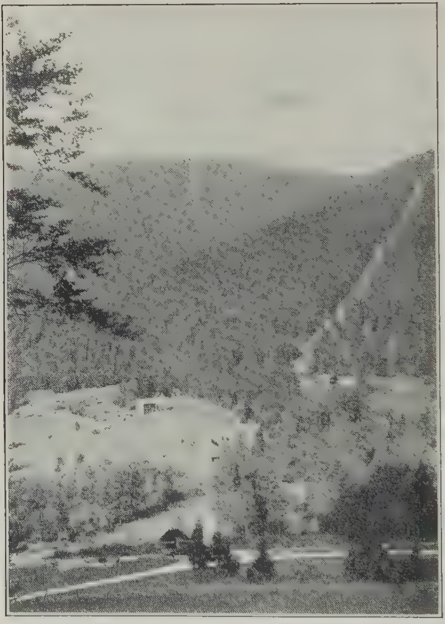

FIG. 257. AUSTRIAN EVERGREEN FORESTS

These trees were planted under a system of constant use and constant replanting of forest trees. The cleared tracks down the mountain show where the logs slide down to the mills. (Photograph by the Austrian Forest Service)

Shade trees should be pruned to remove all dead limbs and to keep the trees in proper form. Even trees which have begun to decay may be pruned, the decayed places carefully cleaned by removing decayed and decaying wood, and the holes filled with cement, which is later painted over. Thus the sources of further danger to the tree are removed. Tree surgery of this sort has now become a common and useful profession. Can you find trees that show how trees may heal over wounds?

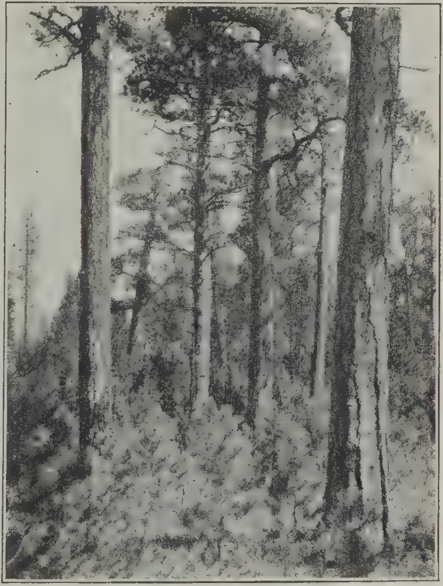

FIG. 258. AN EVERGREEN FOREST REPLANTING ITSELF

An old yellow pine forest in Montana. (Photograph by the United States Forest Service)

309. *Conserving and using trees and timber. Forests are for use, not merely to be kept. Even in the great national and state forest reserves a wise policy of using the old trees and planting new ones should be followed. Although these preserves are for the people's use and for homes for native wild animals and plants, a policy of use and replanting aids rather than hinders their purpose. Proper conservation of forests means proper using and maintaining.

†Almost every person needs wood for something. Wood is still much used for fuel. Large quantities of lumber are constantly used in the construction of buildings, in mak-

ing furniture and various farm and household implements, and in numerous other ways. Over three hundred feet of lumber for each person are used in the United States each year. The use of wood pulp (see page 375) has become one of our largest industries. The use of iron and steel has not removed the need for timber. It seems likely that we shall still need timber as long as can now be foreseen. The use of trees for shade and for the decoration of our homes, our parks, and our streets, drives, or roads seems likely to continue. The older civilizations of Europe are the ones which make most use of trees for beauty, pleasure, and recreation. It seems clear that citizens in such a land as ours should have a practical policy for using the forests and for reforestation (Fig. 257). We have hun-

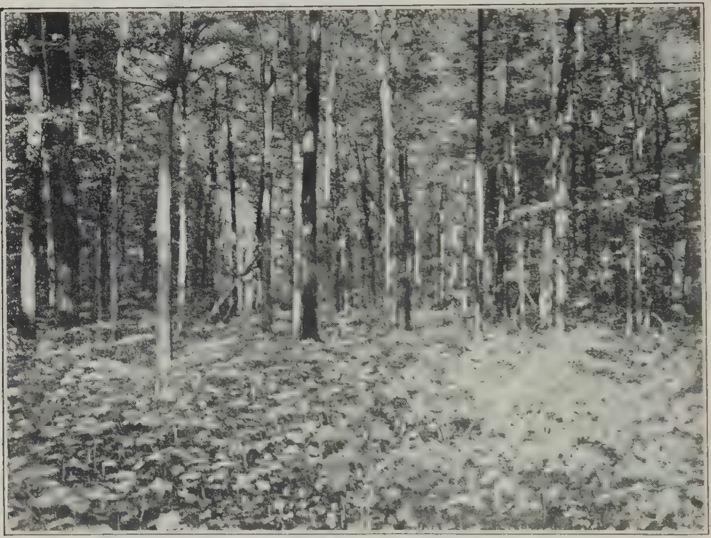

Fig. 259. A Deciduous Forest Replanting Itself

dreds of thousands of acres of former forest lands now without trees and not good for cultivation. It is not easy to get governments to plant trees for future generations, but important beginnings have been made.

†In many parts of the country, particularly in New England, in upper New York, in the states about the Great Lakes, and in some of the Southern states, lands which were once cultivated are sometimes deserted by farmers. In such cases nature hastily undertakes to replant forests upon such lands (Figs. 258 and 259). The kinds of trees are not always the best, but in another generation fine forests will exist in many of these places.

Special Report. Secure from your state forestry office bulletins telling what your state is doing toward reforestation upon areas that once had forests or toward developing new forest areas. Make a class report on this topic.

Special Report. Visit a local lumber yard. Learn the kinds of lumber sold and the region from which this lumber was secured. Learn how much local timber is used, what kinds are used, and for what purposes. Make a class report on these questions.

Special Report. Visit a large building under construction and prepare a list of the ways in which timber is being used and the ways in which other materials, such as steel and cement, are being used as substitutes for timber.

310. Memorial trees. Many people associate some of their own personal experiences with certain old trees, and like to visit these trees and recall events of days long since past. Thus in central Indiana a white-oak stump still stands as the monument of the former giant tree under which the church services of an entire community were held more than a century ago. In Coles County, Illinois, a black locust tree and an immense lilac bush mark the site of the first Illinois home of Abraham Lincoln. In Cambridge, Massachusetts, fenced within a small space between busy modern streets, there was lately an elm tree (Fig. 260) under which, on July 3, 1775, General George Washington accepted command of the armies of the Revolution. In the "big tree" forest near Santa Cruz, California, one is shown the tree under which it is said the white people and Indians of California held their final peace conference. Other great trees have been named for important men in the history of our country.

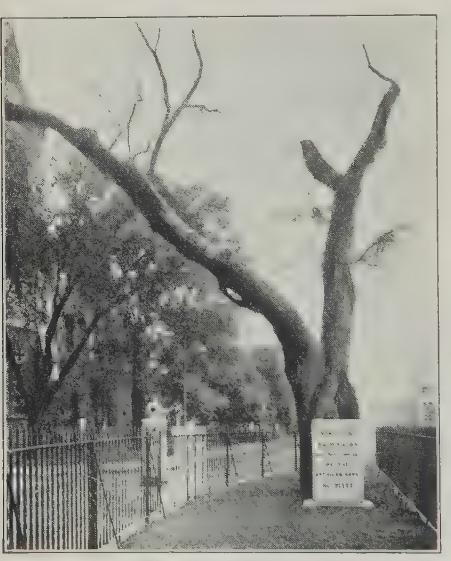

FIG. 260. THE WASHINGTON ELM
This tree was blown down in 1924

Many thousands of trees have been planted and named for those who lost their lives in the World War. Sometimes the city has done this memorial-tree planting, sometimes it is done by special organizations, and sometimes it is done by the families and friends of those thus remembered. It is peculiarly fitting that a long-lived growing tree should be made a monument to those whose acts still live, though they themselves are gone.

Many years ago a special tree-planting day was established called Arbor Day. Its purpose is not only to plant trees but to discuss the place of trees and forests in the pleasures and work of people. Organizations such as the Boy Scouts have adopted programs of study and of action which have greatly increased public knowledge about trees and the general desire to plant them and care for them.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. The best trees for timber are those which grow far apart.
2. In former times there were about **twice as many** **four times as many** **six times as many** **ten times as many** **twenty times as many** acres of native forests as there are now.
3. The original forests were destroyed chiefly by burning and lumbering.
4. The branches of trees die if they have very much sunlight.
5. Wherever a branch joins a trunk, a knot is formed in the trunk. The lumber with fewest knot holes is therefore made from trees which grow far apart.
6. Few forest fires are caused by careless campers and hunters.
7. Forest fires are sometimes started by lightning.
8. Forests should be conserved **by cutting no more trees** **by planting young trees as the old trees are cut** **by cutting very few trees** **by cutting all standing timber, then planting young trees in the area from which the timber has been removed** **by making laws forbidding the use of all lumber for building purposes.**

CHAPTER XXVIII

FARM AND GARDEN

Some Questions this Chapter Answers

How have soils been formed? Are soils now being formed? Do all soils contain water? How much water do farm plants carry into the air? How are farm and garden irrigation systems constructed? How may soils be kept fertile? What is the importance of careful tillage of the soil? What animals are helpful to the garden? What ones are harmful? What are the most common plant diseases of the farm and garden? How may farm animals be improved?

311. What is soil? We have discussed the dangers from floods (see page 487) and the making of soil (see page 486). Why do we give so much attention to a substance which some people call dirt? Are soil and dirt the same thing? Dirt is matter, whether soil or anything else, found in places where it does not belong or where it is not wanted. Soil on one's hands is dirt, but soil in the field, woods, or garden is not dirt. What is the soil?

*If we examine the surface of a rocky cliff, we usually find no soil on it. Careful examination will enable us to find some plant growth even on the rock. Gray or reddish-brown plants called lichens adhere to the rocky surface and grow until a scale-like mass has been formed (Fig. 261). During their growth these plants dissolve a little of the surface of the rock, so that when the masses of the plant fall from the rock some rock particles fall with it. New lichens then grow in the same way. The old lichens decay, and they and the rock materials become the home of other plants, such as mosses, ferns, and very young plants of still other kinds. The processes of freezing and thawing (see page 291), the roots of plants (see page 292), and the products of animals help to build up more and more soil materials. In almost any region of rocks one may see various stages in the never-ending processes of soil-making.

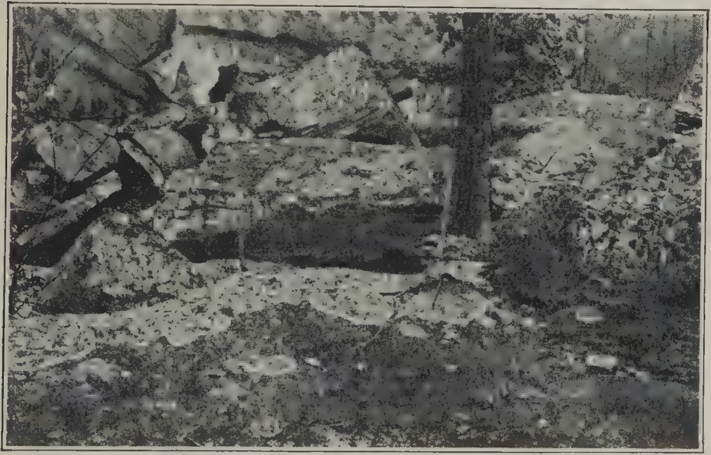

FIG. 261. THE BEGINNINGS OF SOIL-MAKING

Lichens growing on stones. In the spaces between the stones enough soil has collected to permit ferns and some other plants to grow

†The products of decay and the broken rock are gradually washed away (Fig. 262), and these materials may spread over the valleys (see page 306). New growths of plants and animals constantly make their additions of humus (see page 486).

When deep beds of rich soil have been formed (Fig. 263), the kinds of plants which started the process are no longer found, but in this soil there are plants and animals that cannot live on rocks with the small amount of soil there available.

†Winds sometimes blow fine sand, dust, or clay and deposit these in large quantities. Soils may be blown to or from the places where people would like to have them. In times past great masses of ice called glaciers (Fig. 172, p. 296) carried rocks and soils great distances and thus moved the soils of one country to other countries far away.

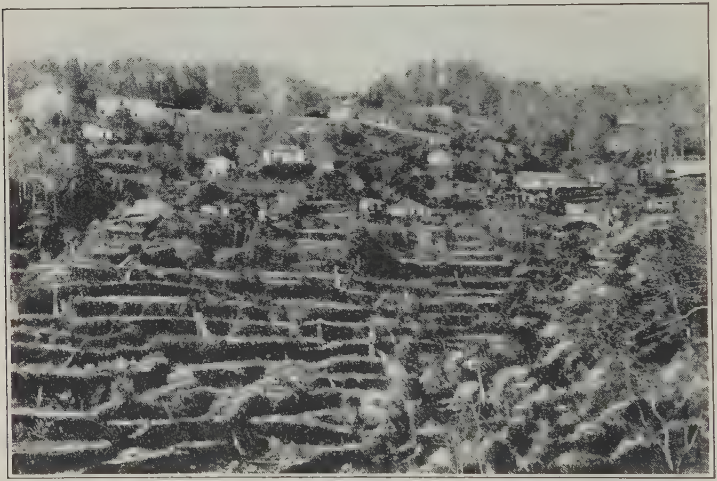

FIG. 262. TERRACED GARDENS ON THE MADEIRA ISLANDS

What have these people done to prevent the erosion of their soil?

*It is clear that soils in different places will have different composition (see page 308). The United States Department of Agriculture has made a list of the rock materials which compose soil and has given the diameter of the materials of each kind. These materials are of all sizes, and grade into one another. The kinds of rock substances and their measurements in the metric system are given below (it is not important to try to remember the exact sizes of each kind):

ROCK SUBSTANCES OF THE SOIL

NAME	DIAMETER OF PARTICLES IN MILLIMETERS
Gravel	2.0–1.0
Coarse sand	1.0–0.5
Medium sand	0.5–0.25
Fine sand	0.25–0.1
Very fine sand	0.1–0.05
Silt	0.05–0.005
Clay	0.005–0.000

In addition to the rock particles the soil contains humus. The humus varies widely not only in amount but also in the sizes of its particles. The larger the amount of this organic matter in soils, the less the soils weigh per cubic foot. For this reason humus soils are called light soils. In swamps or in areas that once were swamps the amount of decayed vegetation is sometimes so large that the soil is almost like chaff, and is called a chaffy soil.

Experiment 56. What percentage of water is in the soil? What percentage of the soil is organic matter? Bring to the laboratory several samples of soils secured from different regions. Weigh equal volumes of each soil. Then dry the soil slowly, stirring from time to time, taking care not to have heat enough to burn the organic matter. When the soil is dry, weigh the samples again. Then heat the samples hot enough to burn all organic matter, and weigh again. Calculate the percentage of moisture and of organic matter.

What factors keep this experiment from giving absolutely accurate results?

312. Soils and water. In nature there is no absolutely dry soil (see page 56), but the amount of water contained in the soil varies greatly. Some kinds of swamp plants can grow in soils no matter how much water there is, and desert plants can grow with very small amounts of water. Most farm and garden plants cannot grow well in extremely wet or extremely dry soils. For this reason drainage ditches are used in the most successful farms and gardens.

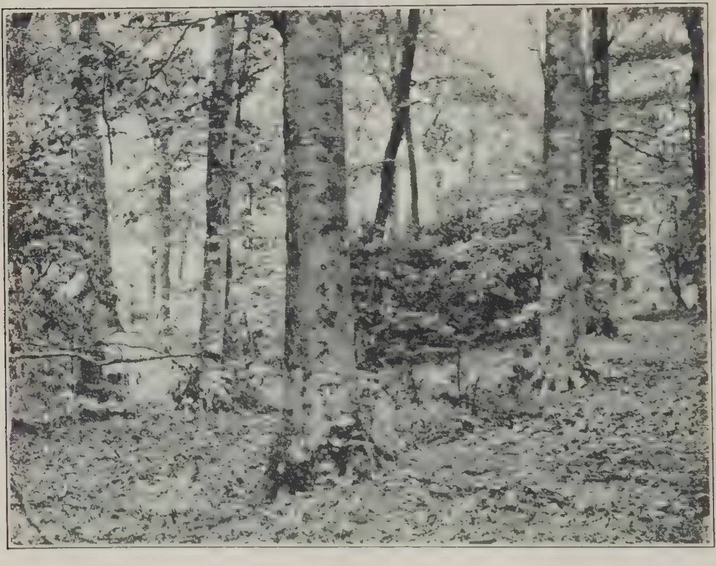

FIG. 263. THE FOREST FLOOR AND SOIL-MAKING

Under the forest trees masses of leaves and twigs are constantly decaying and helping to make the soil richer. (Photograph by the United States Forest Service)

*In dry countries irrigation ditches are used for carrying water to the soil, and drainage ditches for carrying away any surplus[1] water. When water is applied on the surface of the soil through irrigation, certain soil salts (see page 116) slowly collect on or near the surface and may prevent growth of crops; hence even in irrigated soils drainage ditches are needed to carry these harmful salts downward and away.

When soil is composed of finely divided particles a film of water adheres to each particle, and the particles fit together so as to form capillary passages (see page 354). These passages draw water upward from deeper moist soil and may thus serve to keep a constantly upward-moving supply of water. This supply is not always sufficient for the growth of heavy crops during unusually dry weather, yet even a little water in the soil helps the crops if it is conserved. If the surface layer of soil is hard, the capillary water may evaporate and be lost without helping the plants to grow; if the surface is well cultivated, however (see page 132), the capillary passages in the surface layer are broken up and do not carry water to the surface. Tilling the surface, therefore, conserves the water in the soil. In regions where irrigation is necessary a finely cultivated surface layer helps to hold the water that is put into the land.

313. Amount of water used by farm and garden plants. The great importance of the supply and control of soil water is seen when we learn the amounts of water used in producing some of our common crops, as in the table on page 508.

It must be kept in mind that the solid materials of the plant, except the carbon, are from the soil. These materials are in very dilute solutions, and large amounts of water must pass through the plant in order to provide the needed amounts of such compounds as nitrogen, iron, sulphur, potassium, and phosphorus. When we recall that much soil water is evaporated directly from the soil, the tremendous amount of water which goes from the soil and from plants into the air (see page 48) is appreciated.

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[1] *Surplus* (sur′plus): more than is needed.

WATER USED BY PLANTS IN PRODUCING A TON OF DRY PLANTS

PLANT	TONS OF DRY MATTER PER ACRE IN CASES REPORTED	TONS OF WATER USED PER TON OF DRY MATTER	INCHES OF WATER USED PER ACRE
Oats	8.89	503.9	39.53
Corn	6.59	270.9	15.76
Clover	4.39	576.6	22.34
Peas	4.009	477.2	16.89
Potatoes	6.995	385.1	23.78

In some dry regions the soil has too little moisture, and not enough rain or snow falls each year to meet the yearly needs of farm and garden crops. In such places a practice called dry farming has been introduced. This consists in conserving the moisture for two or more years, then growing a crop, then conserving again and following with another crop when there is moisture enough. When the soil surface is kept mellow the moisture does not evaporate readily. By going over the soil surface after a rain or whenever the soil begins to become hard, the surface is kept mellow and most of the moisture is held. Dry farming has been practiced and studied, and calculations have been made of the crop production that may be expected from different numbers of inches of rainfall. The following set of calculations is made in terms of the amount of wheat that may be expected from the conserved rainfall in dry-farming areas:

1 inch of water to the acre will produce 2½ bushels of wheat
10 inches of water to the acre will produce 25 bushels of wheat
15 inches of water to the acre will produce 37½ bushels of wheat
20 inches of water to the acre will produce 50 bushels of wheat

Dry farming uses cheap lands, else it could not be successful. Such farming has not extended rapidly during recent years.

314. *Irrigated farms and gardens. There are many regions where the soil has all the qualities that are needed for producing crops, with the one exception of water. Deep wells from which water is pumped are sometimes used successfully. Great reservoirs into which the water is pumped are placed in high locations. From these the water is allowed to run to the fields in either open or buried ditches.

*The most extensive irrigation projects make use of mountain streams which are sometimes far away from the lands to be tilled. Valleys are made into immense lakes by the construction of enormous cement retaining-walls. These reservoirs are usually owned and managed by companies, sometimes by state or national organizations. The water is delivered to the farmer through canals and is paid for like anything else he buys. Thus the mountain rains and snows or even the water from glaciers (Fig. 172, p. 296) may be held in reservoirs and be used in crop production instead of running off directly to the oceans. In Texas, California, Arizona, Colorado, and other states so situated irrigation is of the greatest importance. In fact, irrigation is profitable (Fig. 264) in any region with a good climate and with an annual rainfall of less than twenty-five inches per year. If twenty-five inches of rainfall should be well distributed over the growing season, it would be sufficient for some kinds of crops. However, in

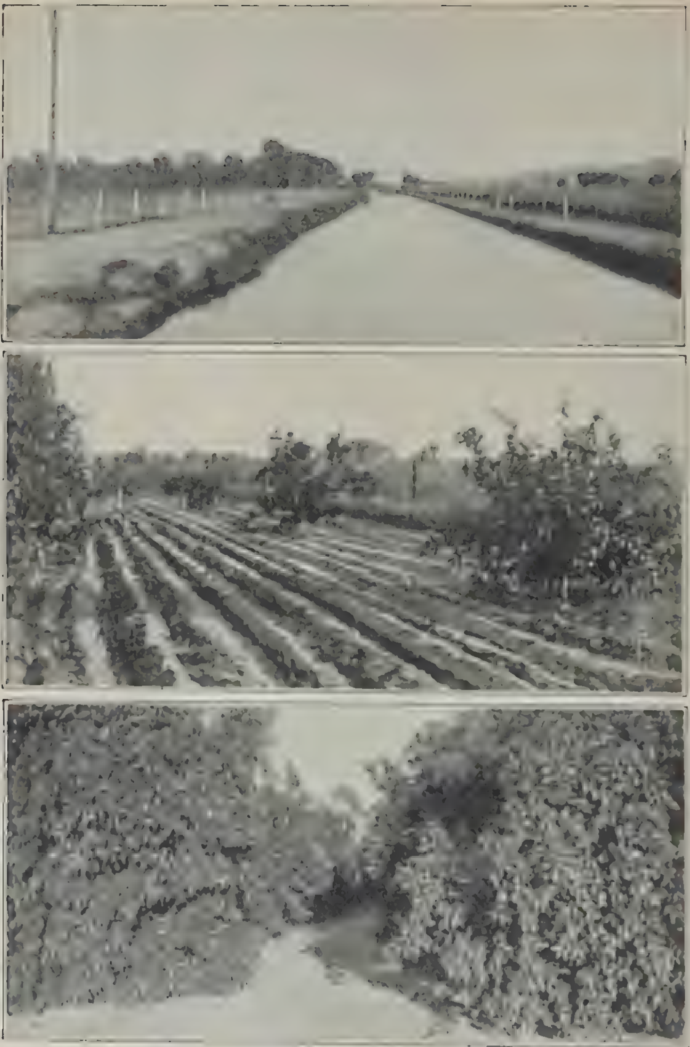

Fig. 264. Arizona Irrigation Canal, Young Grapefruit, and Mature Grapefruit grown on Irrigated Land

Photographs by James E. Wilson

dry regions evaporation is rapid; and unless rainfall is abundant, well distributed, and well conserved, irrigation is necessary.

Irrigation favors types of crops which respond to constant care, such as fruits, garden crops, sugar beets, and alfalfa. Wheat, corn, and other grains thrive under irrigation, but they can be produced more cheaply in regions of slightly less favorable climate and of naturally abundant rainfall.

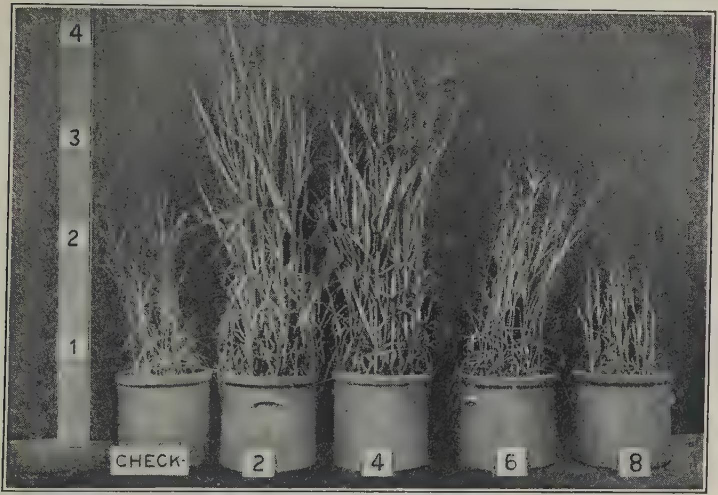

FIG. 265. WHEAT PLANTS GROWN WITH DIFFERENT SOIL SUBSTANCES

The soil in the check pot received no nitrogen. In numbers 2 and 4 nitrogen was readily available. In numbers 6 and 8 nitrogen was slowly available. (Photograph from Agricultural Experiment Station, New Brunswick, N. J.)

315. †Keeping the soil fertile. Plants must have favorable soil materials in order to grow at their best (Fig. 265). The Indians grew crops in one place for a while, and when the soil began to be less fertile they took new fields in other places. White people did much the same as long as there were unused rich lands to be had. When the level plains were first plowed, men thought the soil would always be fertile; they thought that the fertility of several feet of rich black humus lands could never be exhausted. That time has passed, and they have begun to learn that successful farming depends in large part upon keeping the soil fertile.

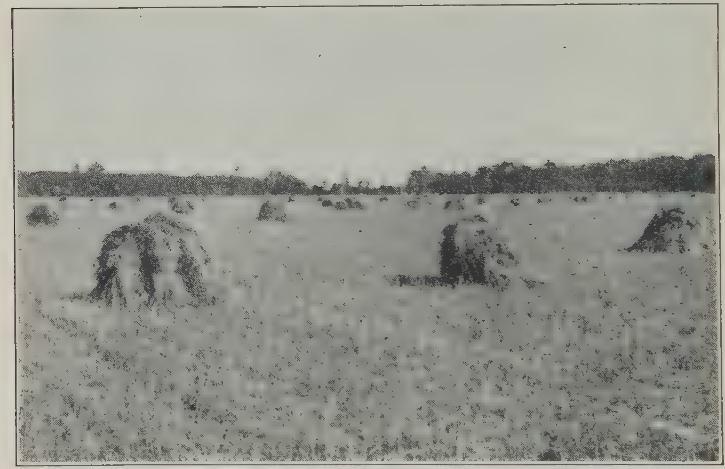

FIG. 266. A WHEAT FIELD WITH UNFERTILIZED SOIL

Photograph by the United States Department of Agriculture

†Soils are made fertile by having them include large amounts of humus or other fertilizers (Figs. 266 and 267). If these are not added and if crops are taken from soils every year, the soils must become poorer each year. As much as possible of the refuse of each crop should go back into the soil. Green crops, such as clover, alfalfa, and cowpeas (see page 419), add to the soil's fertility. Plowing a

green crop into the soil is of great value. Barnyard manure should constantly be used when it can be had. Prepared fertilizers may be purchased and used when manure cannot be had.

†When crops have grown on a piece of land for several years it sometimes happens that acids (see page 116) have slowly collected until crop plants do not thrive. Certain weeds, such as sour dock and sheep sorrel, which grow well in acid soils, are often regarded as nature's indication that the soil has become sour. A special test (see page 116) will show whether soils are acid. When they are, lime or finely ground limestone (see page 327) should be spread over the ground and worked into it by cultivation.[1] The lime

FIG. 267. A WHEAT FIELD WITH FERTILIZED SOIL

Photograph by the United States Department of Agriculture combines with the acid, which then no longer hinders crop growth (Fig. 268). Acid in the soil is one of the most common causes of loss of fertility.

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[1] *Cultivation* (kul ti va'shun): the act of cultivating or the state of being cultivated.

316. *Soils in different regions. In regions of mountains or hills the soil is likely to contain gravel or rock, and not likely to contain large amounts of humus. In plains or river valleys less rock and more humus are likely to be found. In regions that once were swamps, there are likely to be large amounts of humus and small amounts of gravel, sand, or clay. These different kinds of regions usually produce crops of plants that are somewhat characteristic of the regions themselves. Thus the mountain or hill regions are better adapted for trees and pastures or grazing lands. The plains and valleys are better suited for growing the grain crops, such as corn, wheat, and oats,

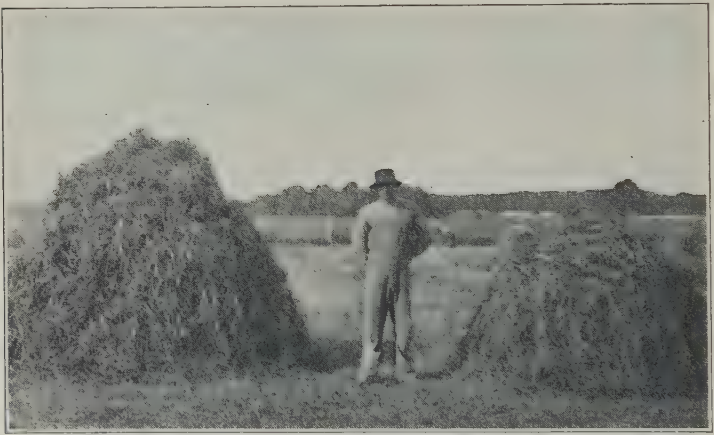

FIG. 268. ALFALFA GROWN WITH AND WITHOUT LIME IN THE SOIL
The alfalfa on the left of the picture was grown with lime and that on the right without lime. (Photograph by the United States Department of Agriculture)

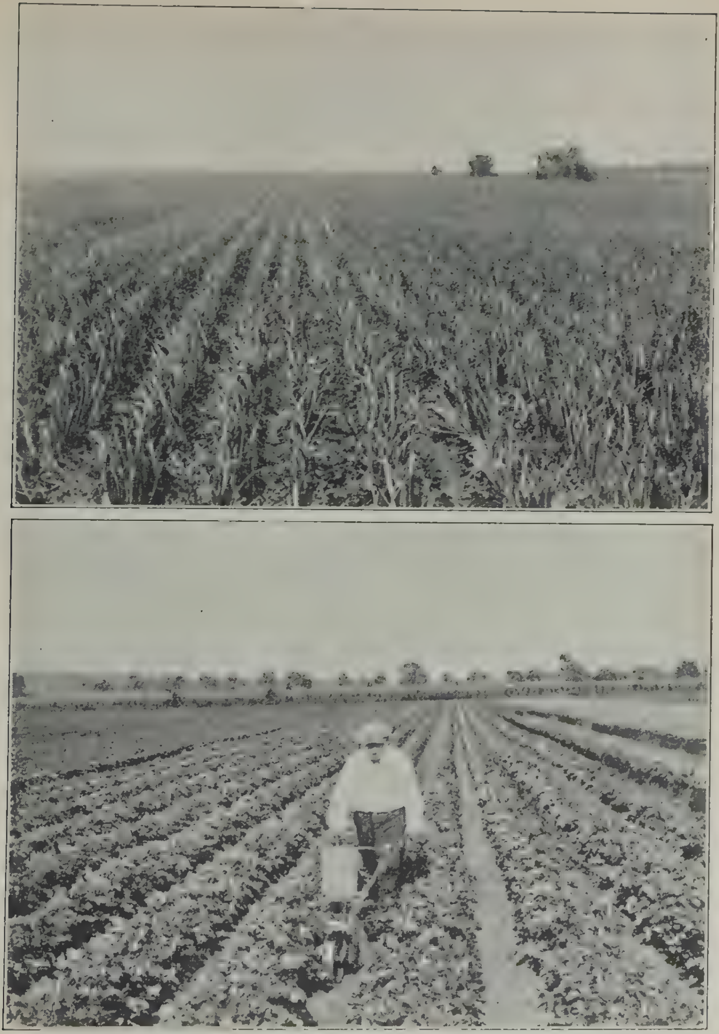

FIG. 269. RECLAIMED SWAMP LAND USED FOR GARDENING

Upper picture shows an onion garden; lower one shows a celery garden. Why is such soil suited to gardening? (Photographs by Eugene J. Hall) and for cotton and sugar beets. The soils which were once swamps are better for gardens or for truck crops such as celery and onions (Fig. 269). Of course all these regions may be used for growing many plants besides those mentioned. In each region there are added such crops as those found in orchards and vegetable gardens.

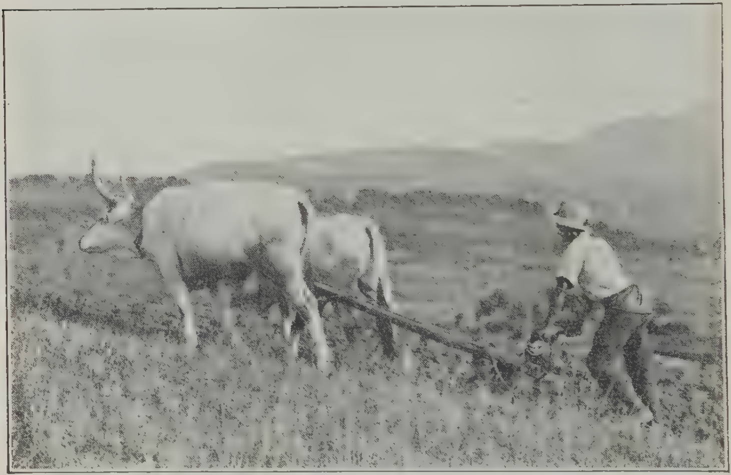

FIG. 270. PLOWING IN ITALY WITH OXEN AND A PRIMITIVE PLOW

New soil regions are being developed by draining swamp areas. There are large unused swamps that will be available for agriculture and gardening when their surplus water can be drained off. The rich swamps which are not useful because they have too much water, and the rich desert areas which are not useful because they have too little water, offer interesting problems. Irrigation and drainage are man's devices for controlling water in the soil.

†The soil is a nation's storehouse — its permanent bank deposit. Productive soils make possible the crops upon

which the world depends. What would happen if all one year's crops should fail? Agriculture is the foundation of national prosperity and happiness and is therefore the most important industry.

317. *Preparing and tilling the soil. In some farming regions the crop is planted in rough and poorly plowed soils (Fig. 270). Most people in progressive countries now know that poor cultivation means poor crops. The roots of plants grow rapidly in finely tilled soils. If moisture and the needed soil substances are available, the roots will supply these constantly to the plant, and growth may be rapid. The best farmers cultivate their crops before the crops are planted by making sure that the soil is mellow (Fig. 271) and that the "seed bed" is a favorable place for young plants to get started.

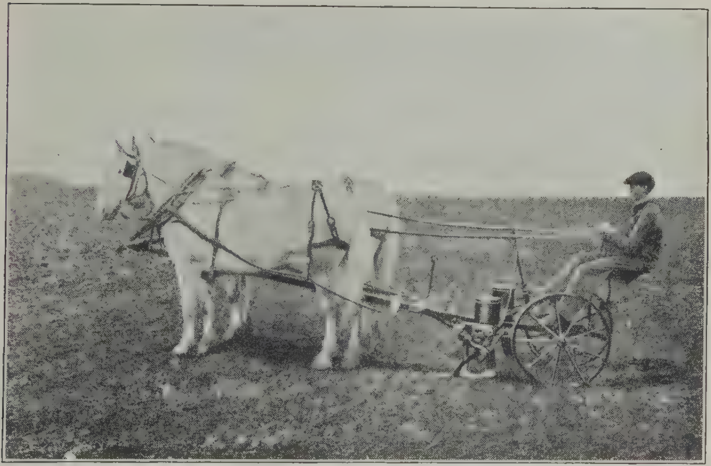

FIG. 271. SOIL SHOULD BE WELL TILLED BEFORE PLANTING THE CROP

Photograph by Eugene J. Hall

*When the crop is started, cultivation must continue. Weeds — plants which are not wanted — begin to grow. Weeds use part of the soil moisture and soil compounds. They may spread their leaves over those of the desired garden or field crops and thus cut off the sunlight. Cultivation is partly to keep the weeds out and partly to keep the soil mellow so that crop plants may have proper moisture.

Project. To find the effect of cultivation on a crop of lettuce. Plant two lettuce beds with rows of lettuce six inches apart. Have all the conditions in both beds as nearly alike as possible. Cultivate the soil in one bed every other day for two weeks, beginning as soon as the lettuce plants first appear. Be sure not only to keep the soil mellow but also to remove the weeds from this bed. Do not cultivate the other bed. Describe the results.

318. †Planning and planting a garden. Gardens for vegetables or for flowers should be so planned that when the plants have grown they will make an attractive appearance. This means that those who make the plan must know what the appearance of the plants will be when they are grown. There are many seed-supply firms whose catalogues include pictures of plants and plans for gardens both for vegetables and for flowering plants.

†Many kinds of garden plants should be started before they are placed in the garden. In this way they may have a month or more of growth before the season permits outdoor planting, and thus an earlier crop may be produced. Tomato plants, cabbage, lettuce, and other plants may be started from seed in pots or in boxes in the schoolroom or the home; or small outdoor beds may be covered with glass frames above the seeds planted in the soil. Such

devices are called cold frames. They are used not only to start plants for later garden planting, but large cold frames are used for maturing small garden plants, such as lettuce and radishes, for household use.

†Indoor planting in pots and outdoor cold-frame planting are also used to test a few seeds from those later to be planted in garden or field, to make sure that they are good and will grow when the regular outdoor planting is done.

Transplanting young plants into the garden must be done with care. The plants should be separated so as not to break their roots. Holes in the mellow soil should be made, and the roots should be carefully spread in the bottom of the hole. Fine soil should then be spread lightly over the roots, and water should be poured in to cause the soil to settle closely about the young roots. Then more fine soil should be placed about the plant to make sure that it stands upright while its roots are growing into their new home.

When plants are grown singly in small pots, all the earth within the pot can be transplanted with the plant. This makes an early start more certain.

†Landscape-garden planning and planting offers a great opportunity as a life occupation, just as do agriculture and vegetable gardening. Each location has its own problems which must be solved if the most attractive results are to be secured. Shrubs and trees have their part in the scheme, as do grass plots, drives, walks, and beds of flowering plants. Each community will usually present illustrations of good and poor planning. In general (1) trees and shrubbery belong at the back or sides of the area to be planted, (2) grass plots should occupy the main central spaces, (3) walks or drives should lead almost directly but gracefully to and from the places that they connect,

(4) low shrubs and flowering plants should be arranged here and there along the walks and drives, and (5) a few shrubs, vines, and wild flowers should be placed along the walls of buildings to add a touch of grace and beauty.

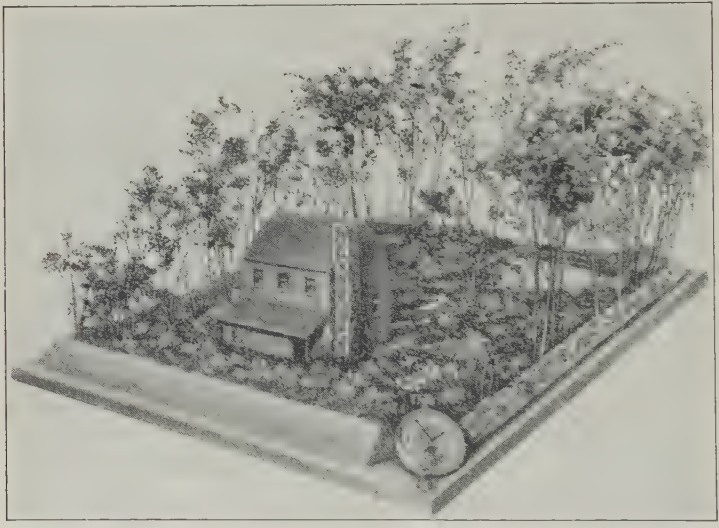

FIG. 272. A PLANTING PLAN BY JUNIOR-HIGH-SCHOOL PUPILS

This landscape plan was designed by two eighth-grade girls. The house and the fence walls were made of modeling clay. Pebbles were stuck into the chimney and the fence walls. The yard is of sand painted green by sprinkling thin paint over it. Hedges of dried moss run beside winding paths in the yard. The pool is a small mirror. The trees by the fence are dried goldenrod stalks. There is a rock garden. Can you design a landscape or garden plan? The watch was used in the picture to give an idea of the relative size of the landscape. (Mrs. Margaret Chapin, teacher)

No detailed rules can be made to apply to all landscape regions. Each must be planned as a unit so as to make the best use of its own spaces and peculiar surfaces and to meet its own building needs. In many cases it is desired to combine a vegetable garden with the landscape plan so as to make a unit of the whole setting for the home.

> *Project.* To make the best plan for either a vegetable garden, a home landscape planting plan, or a combination landscape plan and vegetable garden. Decide the amount of space to be used, and the form. Make a diagram placing the buildings to be included, the walks and drives, and the location and kinds of planting for the whole space. The different plans should be placed on the class bulletin board and discussed in class so that the best points in all the plans may be understood. After your plan has been discussed and improved by the class, make a model of your landscape garden, using modeling clay for buildings and walls, sand for driveways, colored sponges for trees, and so on (Fig. 272). Paint your model in suitable colors.

319. Some animals of the garden. In earlier chapters we have learned something about birds, insects, and toads. These are of special importance in the garden.

†The insect friends of the garden are important. In either city or country the garden may have a colony of honeybees. Bees help the garden by carrying pollen (see page 404) from one flower to another as they go about gathering the nectar from which they make honey.

†The ladybird (Fig. 221, p. 405) is a beautiful and useful garden insect. It feeds upon smaller insects, such as plant lice. The plant lice (see page 397) are very destructive to young and tender plants, hence the ladybird should not be killed. Destructive insects are always to be feared as enemies of both vegetables and lawn plants. When any one kind becomes abundant, specimens should be sent to the state agricultural experiment station with the request for advice as to what to do.

A few toads in the garden are always to be desired. Toads feed on insects. They hide under garden plants and close to them and destroy many of the insect pests which would devour the plants. People who do not know that toads are helpful sometimes wish to destroy them. By killing the toad they suffer for their ignorance.

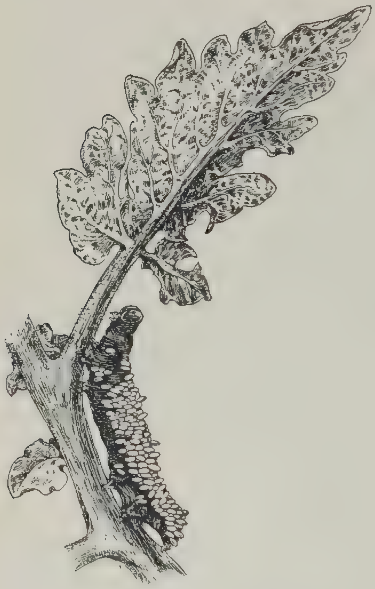

FIG. 273. A TOMATO WORM BEING KILLED BY A PARASITE

A small fly lays its eggs within the body of the worm. The eggs hatch and produce small larvæ, which live for a brief time at the expense of the tomato worm, then produce many small white cocoons upon the worm. From these cocoons a new crop of flies develops

†Several varieties of snakes may live in the garden and be of great use in destroying harmful insects. Only a few of the numerous varieties of snakes are poisonous and therefore dangerous. Most of them are harmless. Besides insects, snakes eat mice and many other small animals which attack the crops. Snakes are often treated cruelly and are killed in great numbers by people who do not know them to be the valuable animals they are.

†Much has already been said about the food of birds (see pages 394–397). The plantings suggested about the home will prove attractive nesting places for several kinds

of birds. The constant presence of the birds and their care of their young will help to insure the successful growth of garden and lawn plants. Why?

> *Project.* To find how many kinds of birds live in one city block or about one farm home. Make a diagram of a city block or of a farm home. Place on the diagram a mark for each bird's nest, with the name of the kind of bird. Learn what you can of the kinds of food these birds eat and then make a statement of their value to the community.

The value of birds for their beauty, their songs, and the cheerfulness they add to the landscape is beyond estimate.

320. *Plant diseases of farm and garden. It is not possible or desirable to list in this book all the parasites which attack farm and garden plants. There are many of them, each with its own way of living and each requiring its own treatment for prevention (Fig. 273). Molds, mildews, and rust attack and produce disease upon several kinds of useful plants, such as the leaves of grape, lilac, and apple. Others attack the fruits. Plant lice attack the tender leaves and stems of plants, and scales attack the twigs of fruit trees.

> *Special Reports.* Study one of the chief harmful plant parasites of your community, such as rust on wheat, oats, or barley; smut on corn; potato blight; dodder on clover and alfalfa. Secure bulletins from agricultural experiment stations and prepare a report stating how the parasite lives and what may be done to prevent damage by it.

321. Farm stock and its improvement. Ancient man did not know how to till the soil. Many centuries passed before man learned to cultivate plants for food. Little by little he learned how to have some of the larger animals —

the horse, the ox, the camel, the donkey, and others — serve him in various ways, such as preparing the soil, caring for the growing plants, and harvesting his crops. He learned to use the produce of his farms to grow other animals for food and he learned how to make clothing from their hair or wool and their skins. Very lately science has provided machines to do faster and better much of the farm work formerly done by animals (Fig. 75, p. 132). But though domestic animals are becoming less important as beasts of burden, they are becoming more important in other ways. Now that wild life has almost disappeared, the world depends upon domestic animals and their products for much of its protein food (see page 442), and it is finding more and more uses for leather and furs. Already "fur farms" are being established in many places, where foxes and other animals are grown for their fur.

Special Reports. Make a list of all the different kinds of animals you can think of which are now raised especially for their fur. How many different domestic animals can you list which are raised in various parts of the world for their hair or wool as material for clothing? How many different kinds of skins can you list from which leather is made? How many different kinds of leather can you list, with their special uses? How many different kinds of leather are used in making shoes? Describe the processes used in making a pair of shoes.

Improved breeds of plants and animals are sometimes less affected by parasites than their ancestors were. Thus some kinds of wheat and oats, although they may have rust, are not damaged by it as are other kinds; some breeds of cattle have been found not to be affected by the cattle tick (see page 432) as are others.

In the same way breeds have been developed which produce better wheat, or better cotton, or better wool, or better beef. Plant and animal breeding for improved kinds is a new and important science (Fig. 274). Flowering and other plants have been greatly improved in beauty and usefulness by Burbank and others. If you study farther in biology you will have to pay much attention to such topics as these. There are dozens of experiment stations where plants and animals are being studied in order that they may be improved both for man's uses and for his pleasures.

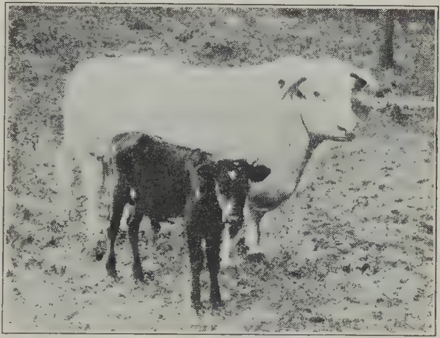

FIG. 274. GOOD STOCK AND GOOD CARE COMPARED WITH POOR STOCK AND POOR CARE

These calves are of the same age. The small one is of the poorest stock and has had poor food and care. The large one is of the best stock and has had as much good food as he could eat and as good care as is possible. Do breeding and care make a difference? (Photograph by Eugene J. Hall)

It is hardly possible that too much attention can be given to the proper care of plants and animals about the home and farm. They, like human beings, cannot do well without reasonably good homes and good food.

Special Report. Select some kind of farm animal — pigs, colts, calves, poultry, or dogs — and describe the proper kind of living place and care for allowing this animal to grow best and to perform its part in the life of the farm.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. A plant which grows upon rocks and assists in reducing the rock to soil is **the rose** **mold** **lichen** **rust** **smut.**
2. Soil particles vary little in size and composition.
3. In the irrigation of farm land it is desirable to leave on the land the extra water which does not sink into the soil.
4. Irrigation is carried on in regions of abundant rainfall.
5. In the following list of states select those in which irrigation would be likely to be used in farming: **Maine** **New Mexico** **Texas** **western Oregon** **Utah** **Arizona** **California** **Florida** **eastern Idaho.**
6. Land is cultivated in order to reduce the growth of ____ and to keep the soil ____.

SCIENTIFIC PUZZLES AND GAMES

The French peasants have a belief which comes down to them from the days of Rome, that they can protect their cabbages from cabbage worms by putting the shell of a hen's egg on the top of a stick stuck into the ground among the cabbages. They believe that the white eggshell attracts the butterflies and that these lay their eggs on the shell instead of on the cabbages. The butterfly eggs then dry out in the sunshine, or if they hatch, the young cabbage worms die for want of food. Fabre, the great French scientist, once asked a group of peasants whether they had ever seen any eggs that had been laid by butterflies on the eggshells, or whether they had ever seen any cabbage worms on the shells. They shook their heads. "Then why do this?" he asked. "It was done in the old days, so we go on doing it," they said; "that is all we know about it, but that is enough for us."

Which of the scientific attitudes (see pages 8–10) are illustrated here?

UNIT XII. KNOWING AND USING MAGNETISM AND ELECTRICITY

CHAPTER XXIX

THE ENERGY OF MAGNETISM; STATIC ELECTRICITY

Some Questions this Chapter Answers

What are some of the important historical facts about magnetism? What are the properties of magnets? What is the field of force round a magnet? What is induced magnetism? How is the earth like a magnet? How may electricity be produced by friction? What are some of the properties of static electricity? What is electricity? What are electrons, and how do they act? What is lightning? How may we protect ourselves from it?

322. Some historical facts about magnetism. People have known for more than two thousand years that there were certain rocks which would attract iron. In some of the Arabian Nights tales there are unscientific stories indicating that ancient people had some knowledge of natural magnets. Some of the ancients knew also that magnets could be made out of pieces of steel by rubbing them against certain kinds of rocks which are *natural magnets*. These rocks are of *lodestone*, one of the compounds of oxygen and iron.

No practical use was made of the knowledge of magnets or of magnetism until someone discovered that when a magnet is allowed to hang free it will turn until it points north and south. This discovery led to the invention of the compass. The compass was probably first invented by the Chinese, and was introduced into Europe about the twelfth century. Before the invention of the compass sailors steered their boats by objects on the shore and by the stars. Consequently they feared to start on long ocean journeys. The use of the compass made possible the voyages of discovery by Columbus and others. These voyages opened new lands and established the fact that the earth is spherical.[1]

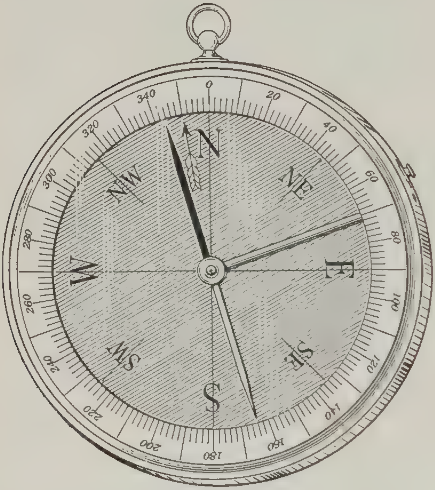

FIG. 275. A MAGNETIC COMPASS

Why is the case made of brass instead of iron?

> Why is the compass considered one of the greatest inventions in human history? How could the sailors steer their boats by the stars?

*Except for the compass, little or no practical use was made of magnetism until the last century. Two important facts were then discovered: (1) that magnetism could be made to produce an electrical[1] current, and (2) that an electrical current is surrounded with magnetism. These discoveries made possible the invention of most of the modern electrical machines which are familiar in our daily lives.

---

[1] *Spherical* (sfer′i kl): like a sphere.

323. ***Magnets.** You are doubtless familiar with the U-shaped magnets which are used with many magnetic toys and games. Sometimes the magnet is not bent into the shape of the letter U, but is straight. U-shaped and bar magnets are always made of iron or steel, because iron and steel are the only substances which can be strongly magnetized.[2] Iron and steel, moreover, are the only substances that can be strongly attracted by a magnet. A compass is only a small bar magnet which is free to turn freely on a point (Fig. 275). The end of the compass which points toward the north is called the north, north-seeking, or *N* pole; the end which points toward the south is called the south, south-seeking, or *S* pole.

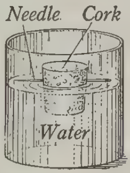

FIG. 276. A HOME-MADE COMPASS

Do not bring near this compass magnets or other objects made of iron or steel. Explain

Experiment 57. How can a magnetic compass be made? Make a magnet out of an ordinary steel sewing needle by rubbing the needle from one end to the other with one end of a magnet. Always be sure to rub from the same end of the needle and to rub in the same direction with the same end of the magnet. Stick the needle (which is now itself a bar magnet) through a small cork so that when the cork is put into water the needle will float above the surface of the water (Fig. 276). Does the needle turn round until it points in any certain direction? Turn the needle in different directions to see whether it will turn of itself so as to point always in a certain direction. Does the floating needle act like a compass?

---

[1] *Electrical* (e lek′tri kl): having to do with electricity.

[2] *Magnetize* (mag′net ize): to make into a magnet.

The first magnetic compasses were probably long pieces of iron which had been magnetized by rubbing them with lodestone; they were probably floated upon a piece of wood in a bowl of water, as you have done with the needle.

324. Magnetism. We can now learn in a few minutes some of the interesting facts learned little by little by scientists through several centuries of patient experimenting.

Experiment 58. Do magnetic poles attract or repel[1] other magnetic poles? Bring the *N* pole of a magnet within a few inches of the floating magnetized needle. What happens? Now hold the *S* pole of the magnet near each pole of the needle in the same way. Repeat until you can fill the blanks in the following sentence so that it will make a true statement:

> A north pole of a magnet attracts (that is, pulls toward it) the ____ pole of another magnet, and the south pole of a magnet attracts the ____ pole of another magnet.

Is the following statement true? If not, can you make it true by changing not more than two words?

> *The same kind of magnetic poles attract each other, and opposite kinds of magnetic poles repel each other.

Experiment 59. We have learned that a magnet will attract pieces of unmagnetized iron or steel. Will a piece of unmagnetized iron or steel attract a magnet? Find out by holding an unmagnetized nail near each end of a floating magnetized needle. Draw a line under the part of the following sentence which makes a true statement with the first part of the sentence:

---

[1] *Repel* (re pel′): to push something away or force something back.

When unmagnetized iron is brought near a magnet
  the unmagnetized iron attracts both poles of the magnet
  the unmagnetized iron attracts neither pole of the magnet
  the unmagnetized iron attracts the north pole but not the south pole
  the unmagnetized iron attracts the south pole but not the north pole
  the unmagnetized iron repels both poles of the magnet

Can you combine the results of the last two experiments and answer this question: If you are given a compass and an iron nail, how can you determine whether the nail is already magnetized or not? Why are surveyors careful to keep pocketknives and other iron articles away from their instruments when they are taking directions with the compass?

Experiment 60. Can you attract a tin can with a magnet? From this experiment which of these two statements do you think is more probably true?

A tin can is made of solid tin.

A tin can is made of iron with a thin coating, or plating, of tin on the outside.

Experiment 61. Does a magnet always have only two poles, an N pole and an S pole, or may it have more than one of each kind of pole? Present a piece of lodestone to the N pole of a magnetic compass. Turn the lodestone round so that different points on its surface are near the N pole of the compass. What do you conclude?

325. The magnetic field of force surrounding a magnet. We have learned that the magnetic energy extends *in all directions* from the magnet through the space round it. The space round a magnet where the magnet can exert a force and do work upon iron or steel is called the *magnetic field.*

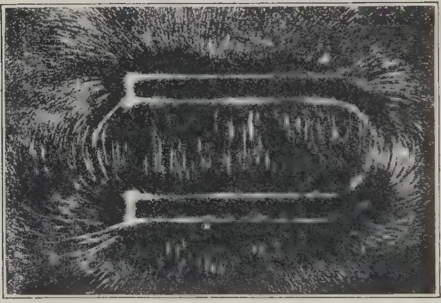

FIG. 277. THE MAGNETIC FIELD ROUND A U-SHAPED MAGNET

Experiment 62. What is the magnetic field surrounding a magnet like? Place a magnet on the table between two books or magazines a little thicker than the magnet. Place a sheet of paper on the books so that its center is over the magnet. Sprinkle iron filings evenly over the paper. Tap the paper gently until you get a clear pattern of the filings (Figs. 277, 278).

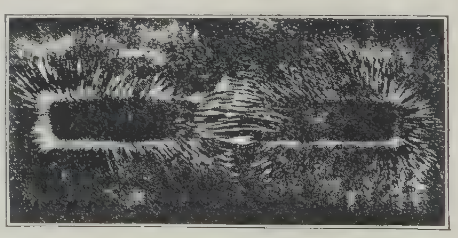

FIG. 278. THE MAGNETIC FIELD ROUND A BAR MAGNET

This and Fig. 277 were made by sprinkling iron filings on blueprint paper placed above the magnet. After the paper with the filings on it had been exposed to sunlight for two or three minutes, the paper was put into water to fix the print. Try this

The lines which the iron filings took when in the field of the magnet are called *magnetic lines of force*. These lines of force go through the air in all directions from the *N* pole of the magnet to the *S* pole.

326. Induced magnetism. When we made a magnet we stroked a needle in only one direction with one pole of a magnet. Will iron become magnetized when we place it against a magnet? when we place it near a magnet?

Experiment 63. Can you make a magnet by induction? Dip one pole of a magnet into a pile of very small steel nails or iron filings (Fig. 279). Do the nails that touch the magnet become magnetized? Do the nails that do *not* directly touch it become magnetized? How do you know in each case? Now, without jarring the other nails, very carefully pull away from the magnet some of the nails that touch it. Do the nails keep their magnetism when they are not touching the magnet?

Hold a magnet in one hand, and with the other hold a nail so that its head is very near the magnet but not touching it (Fig. 280). See whether the point of the nail will attract small nails. Take the magnet away. Is the magnetism of the large nail made greater or less when the magnet is removed?

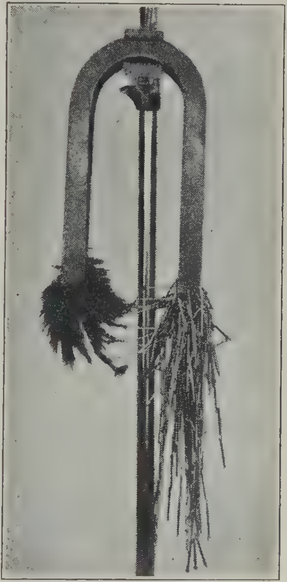

FIG. 279. MAGNETIC INDUCTION

One pole of the magnet was dipped into iron filings, the other into nails. Why do the filings and the nails join, and why do some of the lines of nails extend out to touch the iron stand?

The magnetized iron or steel has *induced magnetism* while the magnet is near it. *The process of magnetizing a piece of iron or steel by merely bringing it near a magnet is called magnetic induction.* Thus the large nail became magnetized by induction, and while it was magnetized it magnetized the small nails by induction. Magnetism is more easily induced into soft iron than into hard steel; but as soon as the inducing magnet is taken away, the induced magnet loses nearly all its magnetism. Thus we say that induced magnetism is temporary and that a magnetized steel bar which holds its magnetism is a permanent magnet.

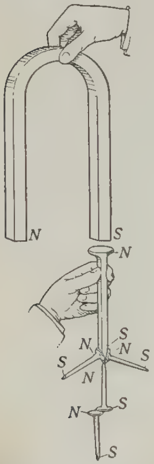

FIG. 280. A MAGNETIC INDUCTION DIAGRAM

Would the larger nail become an induced magnet if you held the point near the magnet and the head away? Try this

Study Figs. 279 and 280. Can you explain why each nail has at the end nearest to the inducing magnet a pole *opposite* in kind to the pole of the permanent magnet, and at the end farthest from the permanent magnet a pole of the *same* kind as the pole of the permanent magnet? Can you explain why the little nails spread apart instead of hanging side by side from the ends of the big nail (Fig. 280)? Does the same reason account for the fact that iron filings stand out from the end of a magnet (Fig. 279)?

327. *The earth a huge magnet. The earth is considered to be a magnet because in most parts of it the compass needle takes a general north-and-south position. The magnetic poles, however, are not located at the geographical[1] north and south poles. For this reason the compass does not point *exactly* north and south in most places on the earth. In our eastern states the *N* pole of the needle points slightly northwest; in the western states, slightly northeast.

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[1] *Geographical* (je o graf′i kal) or *geographic* (je o graf′ik): having to do with geography.

328. Electricity produced by friction. If you have ever stroked a cat's fur in dry cold weather, you have observed a crackling sound as your hand moved along the cat's back. If you did this when the room was dark, you could see sparks on the fur. If you rub a fountain pen on wool clothing, or if you pass a hard-rubber comb through your hair, the pen or the comb will afterwards pick up small bits of paper. (Try this.) In these cases the cat's fur, the fountain pen, and the comb have become electrified[1]; that is, some of the mechanical energy of the rubbing has been transformed into electrical energy.

*Electrical energy of this kind is called static, or frictional, electricity; it is usually produced by the friction caused by rubbing one object upon another. People sometimes confuse static electricity with magnetism, though these two kinds of energy are different. The magnets we have studied are made of iron or steel and attract only iron and steel. On the other hand, many familiar substances can be electrified, and when they are electrified they will attract small bits of almost any substance.

329. Static electricity made up of plus and minus charges. *Experiment 64.* Can static electricity be produced on hard rubber and woolen cloth by rubbing them together? Thread a sewing needle with dry silk thread. Pass the needle through a very small bit of cork. Push the cork to the bottom of the thread as you would string a bead. Suspend the cork as shown in Fig. 281. Rub a fountain pen vigorously with a piece of woolen cloth. Quickly bring first the pen, then the cloth, *near* the cork. Do not touch the cork. Is the cork attracted by both the pen and the cloth? Make a complete sentence answering the question asked at the beginning of this experiment.

[1] *Electrify* (e lek′tri fi): to endow with electricity or electrical energy.

*There are two kinds of static electricity: plus, or positive, and minus, or negative. In this experiment minus electricity was produced on the fountain pen and positive electricity was produced in equal amount on the woolen cloth.

Experiment 65. Can static electricity be produced on glass by rubbing it with silk? Tear a piece of newspaper into very small bits. Scatter some of these on the table. Place two books, about half an inch thick, so that they will hold a glass plate between them, just above the bits of paper. Rub the glass plate *vigorously* with a silk cloth. What happens? Explain. How would you determine whether the silk cloth had a charge after it was rubbed on the glass plate? Does the silk also have a charge? If the glass has a minus charge, what kind of charge should you expect the silk to have?

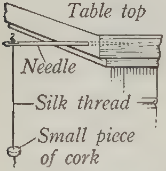

FIG. 281. A HOME-MADE DEVICE FOR STUDYING ELECTRICAL CHARGES

Experiment 66. How do plus and minus charges act toward each other? Electrify the fountain pen and the wool cloth as before. Allow the cork (Fig. 281) to touch the fountain pen in several places. Now bring the minus-charged pen near the minus-charged cork. Do the two minus charges attract each other or repel each other? Again rub the pen vigorously on the cloth, and charge the cork by allowing it to touch the pen. Then quickly bring the plus-charged cloth near the minus-charged cork. Do the two unlike charges attract each other or repel each other?

Is the following statement true or false? If it is false, can you make it true by changing not more than two words?

> *Electric charges of the same kind repel each other and electric charges of opposite kinds attract each other.

Is this statement for electrical attraction and repulsion (that is, repelling) similar to the law of attraction and repulsion of magnetic poles (see page 530)?

330. What is electricity? As yet nobody knows what electricity is. Most of the scientists now believe, however, that the electron theory explains the nature of electricity better than any other. You will remember the statement made on page 113, that all matter is composed of molecules, and that these molecules are spheres so small that a thousand together could scarcely be seen with the strongest microscope. If a drop of water were magnified until it was the size of the earth, the molecules that make up the drop would then be about the size of baseballs. Each kind of molecule contains a certain number of atoms, which are also thought to be spherical. The same kind of molecule always contains the same number of atoms. These atoms are very much smaller than the molecules. In the middle of each atom is a central particle called a positively electrified nucleus. This nucleus always contains one or more positively charged particles, or *protons*. One or more negatively charged particles, or *electrons*, revolve round the nucleus in regular paths called orbits. These orbits, compared with the size of the positive nucleus and the negative electrons, are very similar to the orbits of the planets round the sun. The electrons move in their orbits at enormous speeds, sometimes as great as many thousands of miles per second. It will help us to understand molecules, atoms, and electrons when we are told that a molecule of hydrogen contains one positive nucleus with one electron revolving in an orbit round the nucleus.

331. How electrons act. When the total of the negative charges of the electrons in an atom is exactly equal to the positive charge in the nucleus of the atom, the atom is then *neutral*; that is, it is neither positive nor negative. When an atom loses some of its electrons the total of the negative charges left in the atom is less than the positive charge of the nucleus, and therefore the atom becomes positive. In the same way, when an atom gets extra electrons the total negative charge is greater than the positive charge of the nucleus, and the atom is then negative. To illustrate: when the fountain pen was rubbed on the woolen cloth (see page 535), some of the electrons were rubbed off the atoms of the woolen cloth onto the hard rubber. The result was that the rubber had extra negative charges which made it negative, and the woolen cloth had lost electrons and was therefore positive.

Electrons travel easily through substances such as metals; they will scarcely pass at all through such materials as hard rubber and glass. Any substances through which they do not pass or through which they pass but slightly are called *nonconductors* or *insulators*. *A stream of electrons passing through a conductor is an electric current.* Whenever a body has lost some of its electrons, it is positively charged; it therefore attracts negative electrons which are near and repels other positive bodies. In the same way, a body which has extra electrons is negatively charged; it therefore repels other negative bodies which are near it and attracts positive bodies. Whenever a negative body touches a positively charged body, the negative body gives up its extra electrons to the positive body. The jumping of great numbers of electrons between bodies having opposite charges of static electricity causes a spark such as you saw when you stroked the cat's fur.

FIG. 282. FORKED LIGHTNING

It is not true that lightning never strikes the same spot twice. Giant trees, like the Sequoia trees in California, are struck again and again

Whenever a positively charged body comes near a neutral body (that is, one with equal positive and total negative charges), the negative electrons are attracted to the side nearest to the positively charged body, leaving the opposite side of the neutral body positive. If a negatively charged body comes near a neutral body, the electrons rush to the side farthest from the negatively charged body, leaving the side nearest to the negatively charged body positive. Can you state a reason to account for these last two statements? Can you explain why the bits of paper were attracted to the glass plate in Experiment 65?

332. *Lightning is static electricity. Lightning jumps from one body to another as do the sparks of static electricity which you produce when you rub a cat's fur. Electrical charges are produced in the clouds (Fig. 282) probably by the friction of the wind on the cloud and by the evaporation (see page 48) and condensation (see page 222) of water vapor. If these charges become great enough the lightning may jump between two clouds or between a cloud and the ground just as the sparks jumped between your hand and the cat's fur. Lightning sometimes strikes some object, such as a tree which is higher than the surrounding objects.

Lightning rods are a valuable means of protection from lightning, especially in the country. In the city the soil pipes from the drains (see page 101) serve the purpose of lightning rods. To be effective, a lightning rod must be buried deeply enough so that its end is always surrounded by moist earth, because moist earth is a good conductor of electricity and dry earth is not. This statement means that electrons pass easily through moist earth, but have difficulty in passing through dry earth.

If lightning should strike a house or a barn having lightning rods, the lightning would probably run off on the rods without harming the building. Lightning rods are put on buildings chiefly to protect them by preventing the lightning from jumping, and they serve to conduct the lightning into the ground if it should strike. Thus when a cloud charged with electricity approaches a building equipped with lightning rods (Fig. 283), the rods become charged with the opposite kind of electricity from that of the clouds. The reason is that if the cloud is positively charged it attracts extra electrons to the top of the rod; if it is negative it repels electrons from the top of the rod into the ground. The molecules of air near the point of the lightning rod then take on extra electrons from the rod if the rod is negative or give up electrons to the rod if the rod is positive. The molecules thus become charged. These charged molecules are then attracted to the cloud, which takes away from them the extra electrons they received from the lightning rod or gives them some of its extra electrons to replace those which they gave to the rod, as the case may be. The result is that the cloud is quietly neutralized, or made neutral, so that the lightning flashes from it are smaller; or, if there are enough lightning rods in the neighborhood and other objects to help in neutralizing the charge, the lightning is prevented entirely.

*Although most people fear the lightning, there is really very little danger of being struck by it. It has recently been estimated that the chances that a person will be struck by lightning in his home are only one in many millions. However, it is prudent during a thunderstorm to keep away from the walls through which radiator and heating pipes run, and not to stand between such good conductors as the stove and the sink. Moreover, when you are out of doors during a thunderstorm do not stand under a tree that is not near other trees and do not stand where your head is higher than other objects about you.

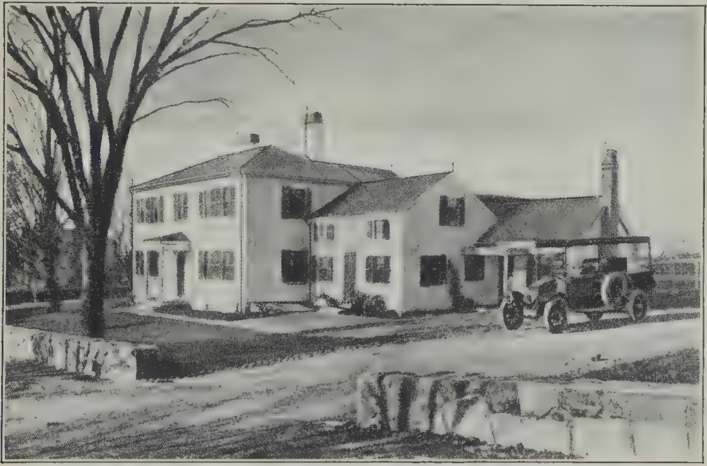

FIG. 283. A HOUSE WELL PROTECTED BY LIGHTNING RODS

How many lightning rods can you see in this picture? Why do wires lead from the rods into the ground?

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. Both ends of a compass needle will be attracted if the compass is placed near one of the poles of a U-shaped magnet or of a bar magnet.
2. The best substance out of which to make a bar magnet is **copper aluminum tin iron sealing wax** ----.
3. A magnet will pick up pieces of **copper tin iron aluminum paper** ----.
4. At the geographical north pole the *N* pole of a compass would point **north south east west in no particular direction.**
5. When a hard-rubber pen is rubbed on woolen cloth, the rubber becomes magnetized.
6. North-magnetic poles attract south-magnetic poles and repel other north-magnetic poles.
7. Like charges attract each other; unlike charges repel each other.
8. Lightning is a form of magnetism.
9. The danger of being struck by lightning during a thunderstorm is very great.
10. During a thunderstorm it is safer to stand in a grove than under a single tree.

CHAPTER XXX

GETTING ACQUAINTED WITH ELECTRICAL CURRENTS

Some Questions this Chapter Answers

What are some of the common units of electricity? How are some common types of electric cells made? What is meant by "series connections"? "parallel connections"? What are complete circuits? grounded circuits? What is the relation between magnetism and electricity? How do dynamos generate current? What is electrolysis? How is electroplating done? How is electrotyping done?

333. †Units of electricity. Whenever a body becomes charged either positively or negatively an electrical pressure is produced. This electrical pressure acts very much like water pressure. The electrical pressure on a body is increased when the charge is increased, just as the water pressure in a tank is increased when the water gets deeper. When a plus-charged body and a minus-charged body are connected by a conductor, the difference in electrical pressure between the two bodies forces a stream of electrons through the conductor from the minus body to the plus body, thus producing an electrical current (see page 538).

†Electrical pressure is called *electromotive force* or *E.M.F.* or *voltage.* The unit of E.M.F. is the *volt*; the unit of electrical current is the *ampere.* Thus volts of elec-

trical pressure send amperes of electrical current through a conductor when the electrical circuit is complete. The circuit is the path made up of the conductors through which the current passes.

When water flows through a pipe, there is friction between the water and the pipe. This friction decreases the current of water through the pipe. The longer the pipe, the greater the friction, and therefore the less the current of water that will flow through it for any given pressure; the smaller the pipe, the greater resistance to the flow of water and the less the current through it. This is only another way of saying that for a given pressure we get a bigger flow of water through a large pipe than through a small one, because the resistance is less.

†When electrical current flows through a wire or other conductor, there is likewise electrical friction. This electrical friction is called *resistance*. Long wires have more resistance than short wires, and small wires have more resistance than large ones. Also, the greater the resistance of a wire, the smaller the current which will flow through the wire. The unit of electrical resistance is the *ohm*.

Can you fill the blank in each of the following sentences with the term "current" or "resistance" or "E. M. F." so that the sentence is correct?

In a complete electrical circuit the ____ forces the current through the circuit.

The current is greater for a given E. M. F. if the ____ is smaller.

The current is greater for a given resistance if the ____ is greater.

334. Electrical current from electrical cells and dynamos. A few of the common types of electrical cells are here discussed; the dynamo will be explained later.

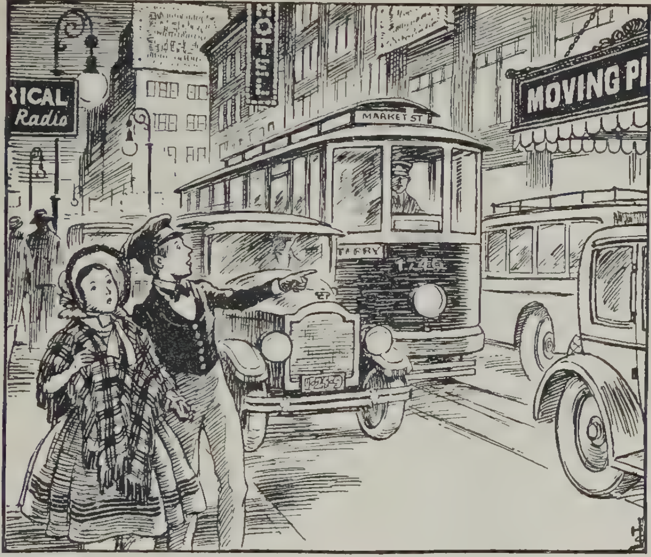

Fig. 284. Eighteen Thirty looks at Nineteen Thirty

What would the boys and girls of a hundred years ago have thought and how would they have acted if they could suddenly have jumped ahead a century to explore *our* environment! Think how magical it would seem to them to see street cars speeding by with no oxen or horses to pull them! Wouldn't they enjoy pushing the button on the wall and flooding the room with light more brilliant than any they had dreamed of! Wouldn't their eyes grow big with wonder and delight at the sight of the electric signs so familiar to us!

They would ask you breathlessly how such wonderful things could be possible. You would tell them, in a matter-of-fact tone: "Why, that's easy. These things are done by electricity — electric currents, you know."

How you would enjoy their puzzled expressions at your explanation! "Electric currents? What are they? We never heard of them." They would know of no books which could tell them anything about electric currents. Not even the greatest scientists of their day could help them much.

*All electrical cells transform chemical energy into electrical energy. The simple electrical cell consists of a copper strip and a zinc strip put into a vessel of water containing a few drops of sulphuric acid (Fig. 285). The copper plate becomes positively charged and the zinc plate negatively charged by the chemical action of the sulphuric acid. This occurs in much the same way that the fountain pen became negatively charged and the woolen cloth positively charged when the two were rubbed together (see page 535). Thus the chemical action of the acid on the metals produces a difference in E.M.F. between the two metals. If the tops of the two strips of metal are connected to each other by a conductor, such as a copper wire, streams of electrons pass at once through the conductor; in other words, a current flows through the wire from the copper or + (positive) strip to the zinc or – (negative) strip. This can be proved by the following experiment.

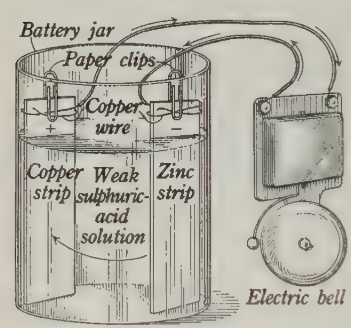

Fig. 285. A Simple Electric Cell

The paper clips are not a part of the cell. They merely serve to press the wires firmly against the metal plates

Experiment 67. Does a simple electrical cell produce a current? Connect an electric bell to the simple electrical cell as in Fig. 285. If the bell does not ring at once, fasten another copper strip to the first one, so that the thickness of the copper strip is doubled.[1] What does the ringing of the bell when it is connected to the simple electrical cell prove?

[1] This modification of the experiment was suggested by Mr. M. R. Van Cleve.

*The simple electrical cell shown in Fig. 285 is of no practical value, because as it acts its pressure (that is, its voltage) becomes weaker, and therefore its current rapidly becomes weaker also. For practical purposes use is made of a dry cell (Fig. 286). The dry cell serves well if it is used only for short periods and is allowed to rest between the periods. The dry cell is convenient because it does not occupy much space and because it will not break or leak. The dry cell is not entirely dry, since the liquid forms a paste which carries the current through the cell. Dry cells are used in operating flash lights, door bells, electrical toys, radio sets, spark coils in gas engines, and in many other ways. Another common type of electrical cell is the storage cell.

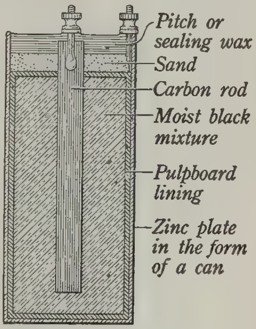

FIG. 286. A DRY CELL

In what ways is it like and unlike the simple cell?

Experiment 68. How is a simple storage cell made and used? Place two large strips of lead in a battery jar. Fill the jar about three fourths full of distilled water and add about a tenth as much sulphuric acid. Connect two dry cells to the lead plates as in Fig. 287, *a*. Can you observe any changes taking place on the two lead plates? After about a quarter of a minute disconnect the two dry cells and connect a small electric bell in their place (Fig. 287, *b*). What happens?

*In this experiment the storage cell was first charged. It was then discharged through the bell. A storage cell does not store electricity. When it is charged, electrical energy is transformed into chemical energy in the cell; when it is discharged, the chemical energy is transformed again

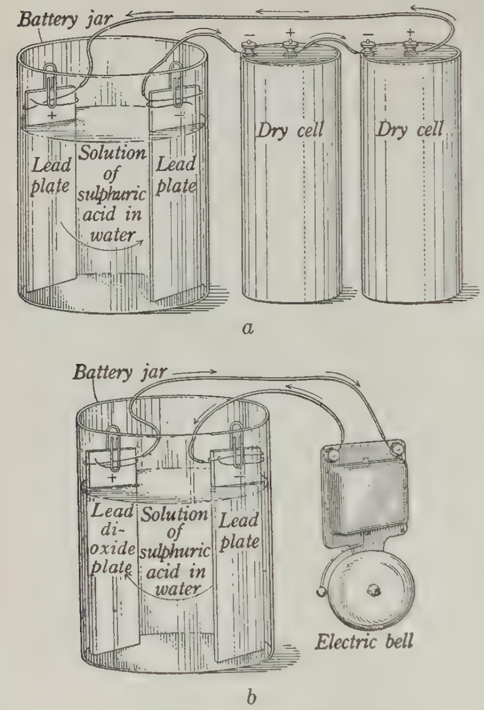

FIG. 287. A STORAGE CELL

a, charging a storage cell; *b*, discharging a storage cell. Is the same plate + in both diagrams?

into electrical energy. Not all the electrical energy used in charging the storage cell can be recovered from the cell as electrical energy when the cell is later discharged; some of this energy is transformed into heat energy and is not usable.

Water has to be added frequently to the cell, because water is broken up by the electrical current into hydrogen gas and into oxygen gas. The oxygen combines with the lead to form a brown coating on the + plate. Commercial storage cells are used in operating automobiles and radio sets, in power houses, in submarines, and the like.

Special Reports. Examine, make diagrams of, and make a report on the commercial storage cell. How does the Edison storage cell differ from the lead storage cell? In what ways is each superior to the other?

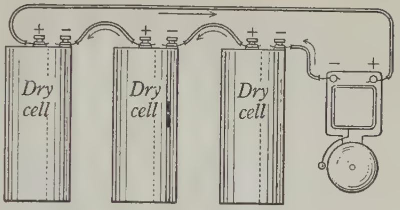

FIG. 288. CELLS CONNECTED IN SERIES

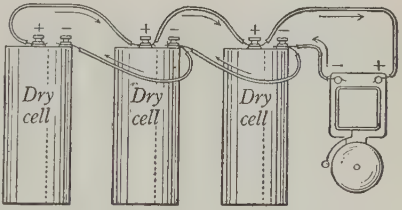

FIG. 289. CELLS CONNECTED IN PARALLEL

335. †Series connections and parallel connections. Usually several cells are used together instead of one alone. Two or more cells connected together are called a *battery.* Cells in a battery are usually connected in *series*; that is, the + pole, or *terminal,* of the first cell is connected to the − pole, or terminal, of the second cell, the + pole of the second to the − pole of the third, and so on (Fig. 288). Sometimes the cells are connected in *parallel,* as in Fig. 289. When cells are connected in parallel, all the + terminals are connected together and all the − terminals are connected together.

Make a statement telling the difference between series connections and parallel connections of cells in a battery.

336. An electrical current flows only through a complete circuit. Wire conductors are commonly covered with some sort of insulating, or nonconducting, material (Figs. 290 and 291). Such material prevents short circuits; that is, it prevents the electrons from escaping from the wire by running off on some other conductor which may touch the wire. No current will flow at any time unless there is a complete circuit; for example, if you trace the current through the entire circuit in Figs. 288 and 289 you will observe that there is an unbroken path from the + pole of the first cell through all the cells and through the wire back to the − pole of the first cell. The liquid in the cells is a good conductor, like the metal wire.

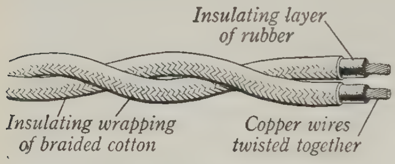
Insulating layer of rubber
Insulating wrapping of braided cotton
Copper wires twisted together

FIG. 290. LAMP CORD

Ordinary electric-lamp cord has two insulating, or nonconducting, layers over the copper wire which carries the current. Silk, enamel, and paraffin are also used to make insulating layers around wires

Whenever wires are connected to terminals in making a complete circuit, all the insulation must be scraped off the ends of the wires so that the terminals make good contact with the bright metal of the wire (see page 538). Thus, in an automobile the spark plugs are connected to the cylinder head, which acts like a wire in grounding the current, and one terminal of the storage cell is connected to the metal frame, which serves as a wire.

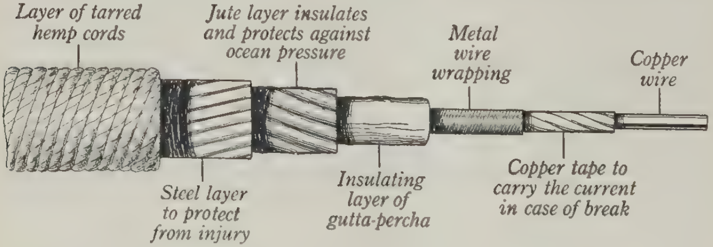
Layer of tarred hemp cords
Jute layer insulates and protects against ocean pressure
Metal wire wrapping
Copper wire
Steel layer to protect from injury
Insulating layer of gutta-percha
Copper tape to carry the current in case of break

FIG. 291. INSULATION ON CABLES

The new Atlantic cable has six insulating and protecting layers over the copper wire which carries the current

Sometimes the circuit is completed by *grounding* it; that is, by connecting the wires from the terminals of the cell to iron water pipes or to the metal frame of an automobile. When wires are thus grounded the earth takes the place of wires in part of the circuit.

337. Magnetism and electricity closely related. *Experiment 69.* Does a conductor which is carrying a current have magnetism? Is it surrounded by a magnetic field? Scrape all the insulation from a few inches of the middle of a copper wire about two feet long. Sprinkle some iron filings on a sheet of paper. Dip the bare part of the wire into the filings. Do the filings stick to the copper? Place the wire above the needle of a compass. Is the needle turned? Now connect the two ends of the wire to the terminals of a dry cell and repeat both experiments. Is the iron attracted? Is the compass needle moved when the wire is placed above it? Is a wire which is carrying current surrounded by a magnetic field? Break the circuit by disconnecting the wire at one terminal. Does the wire still have a magnetic field? Answer with a complete statement the question at the beginning of this experiment.

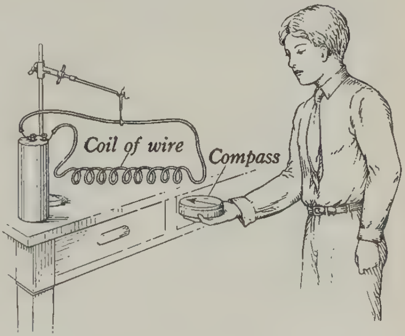

FIG. 292. TESTING A WIRE FOR MAGNETISM

†A little more than one hundred years ago Oersted, a Danish scientist, discovered that a conductor carrying a current of electricity is surrounded by magnetic lines of

force like those round a magnet. This discovery led to the invention of the first electromagnet by Henry, an American, in 1828. Electromagnets are used in almost all modern electrical machines.

> What scientific attitude (see pages 8–10) is here illustrated by Henry's work?

Experiment 70. Does a coil carrying a current have an *N* pole and an *S* pole like a bar magnet? Make a coil by winding the middle of a piece of copper wire, about three feet long, round a pencil or pen. Connect the *bare* ends of the wire to the terminals of a dry cell. Bring a compass near each end of the coil in turn (Fig. 292). Is the coil a magnet while the current is flowing through it? How do you know? Does it have a north pole and a south pole? How do you know? Disconnect one end of the coil from the cell. Is the coil now a magnet? Connect the ends of the coil to the opposite terminals of the cell from those to which you connected them before. Is the coil a magnet now that the current is flowing through it in the opposite direction? Is the same end an *N* pole that was the *N* pole before? Summarize the results of this experiment.

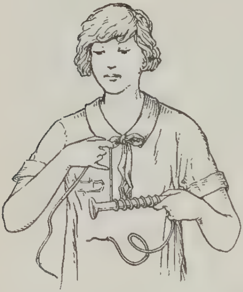

FIG. 293. MAKING A SIMPLE ELECTROMAGNET

Experiment 71. Is the magnetism of a coil carrying a current increased when various substances are put inside the coil as a core?[1] Connect the ends of the coil to the terminals of the dry cell. Place the coil on the table and place the compass near one end of it and far enough away so that it is only slightly deflected[1] by the magnetism of the coil. Without changing the position of the coil, insert in the coil, one after the other, a wooden pencil, a silver pencil, a glass rod, a copper wire, and a large iron nail. Is the magnetism of the coil made stronger when any of these substances is used as a core for the electromagnet? Which substance makes the electromagnet strongest?

---

[1] *Core:* a central body; for example, the core of an apple.

†An electromagnet (Fig. 293) is made of a coil of wire wound round a soft-iron core. The soft-iron core becomes by induction a bar magnet inside the magnetic coil and adds its strength to that of the coil magnet. The electromagnet is a magnet only while the current is flowing through the coil (Fig. 294). Prove this statement. Also, the poles of the magnet can be changed by sending the current through the coil in the opposite direction. Prove this statement.

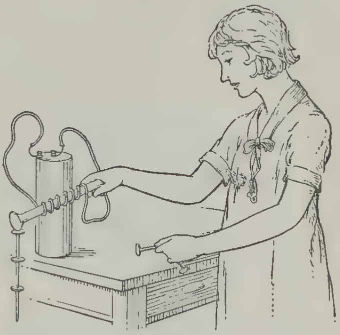

FIG. 294. TESTING A SIMPLE ELECTROMAGNET

What will happen to the nails when the coil is disconnected from the cell? Explain

Fig. 295 shows a great lifting magnet. The magnet is placed over a pile of iron bars. The current is sent through the electromagnet, which immediately picks up several thousand pounds of iron. The magnet is then moved with its load, the current is turned off, and the bars fall. Why? Could you use this same electromagnet to load lead pipe into the cars in the same way? Are the iron bars magnets while they are attached to the electromagnet? Explain.

---

[2] *Deflect* (de flekt′): to turn from its path or position.

We have already learned that a piece of iron or steel becomes an induced magnet when it is brought into the magnetic field of either a bar magnet, a U-shaped magnet, or an electromagnet. In 1831 Faraday, an English physicist and chemist, discovered that an electric current was made to pass through a circuit if part of the circuit was moved through a magnetic field. Currents produced by moving a conductor in a magnetic field are called *induced currents.*

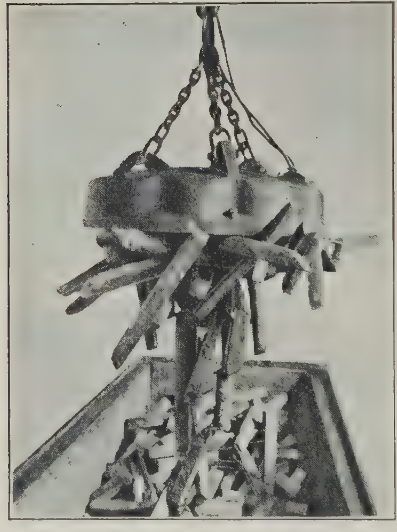

FIG. 295. AN ELECTROMAGNET IN USE

This great electromagnet lifts five tons of iron bars at a time. The coil is in the disk. Note the two wires, one to carry the current to the coil and the other to carry it from the coil

338. Dynamos. *Experiment 72.* How does a dynamo generate (that is, make) electric current? Join the ends of about three feet of copper wire so as to make a complete circuit. Wedge a U-shaped magnet upright between two blocks and arrange the wire and a compass as shown in Fig. 296. Quickly push the wire *down* through the magnetic field between the poles of the magnet. Watch the compass. Note the direction in which the needle of the compass moves. When you pushed the wire down was there a magnetic field round the wire which was above the compass needle? How do you know? Does this prove that there was a current in the wire? Now quickly pull the wire *up* through the field of the magnet. Is the compass needle again deflected? Is it deflected in the same direction when you quickly push the conductor *down* in the magnetic field as when you pull it *up*? Is a current generated in a circuit when part of the circuit is moved through a magnetic field? Does the current change direction when the direction of the conductor through the field is reversed?

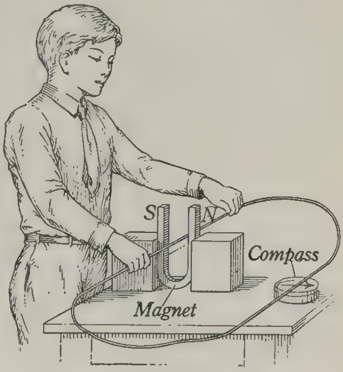

FIG. 296. DIAGRAM ILLUSTRATING THE PRINCIPLE OF A SIMPLE ALTERNATING-CURRENT DYNAMO

*You have just been illustrating the principle of a simple alternating-current[1] dynamo. A *dynamo* is a machine used to transform mechanical energy into electrical energy. A dynamo produces (that is, generates) an electrical current. When the conductor cuts across the magnetic lines of force of the magnet in one direction, as in Experiment 72, electrical pressure is produced which forces a current through the circuit in one direction; when it cuts across the lines of force in the opposite direction (Experiment 72), the electrical pressure is produced in the opposite direction, forcing the current also to change its direction in the circuit.

* A real dynamo is never just a moving wire as in Experiment 72. A real dynamo always consists of a coil of

wire, called an *armature*, which rotates in a magnetic field, with the ends of the coil touching the ends of the circuit. Fig. 297, *a*, will help you to get a better idea of the necessary parts of a working alternating-current dynamo. The ends of the loop of wire which represents the armature in Fig. 297, *a*, are each attached to one of the slip rings. The rings rotate with the armature. The brushes do not rotate; but one end of a brush, which is usually a piece of carbon, touches the ring all the time that the ring is rotating. The rest of the circuit is attached to the other ends of the brushes. Thus when the side of the loop armature marked x is at the top and is going away from you as the loop armature rotates, a current is generated in the loop armature in the direction of the arrow (Fig. 297, *a*). The current therefore goes out through the brush marked A, travels through the external[1] circuit in the direction indicated by the arrows to brush B, and through the slip ring B to the other end of the armature. But when the armature has turned enough so that the side of the wire marked y is at the top

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[1] *Alternate* (al′ter nate): to continue to change back and forth from one condition to another. Thus, alternating current constantly changes; that is, reverses its direction through the circuit.

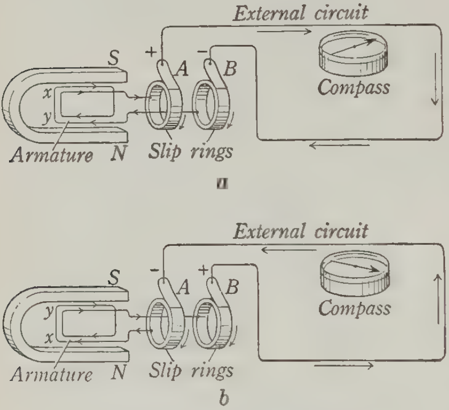

FIG. 297. ALTERNATING-CURRENT DYNAMO

a, Diagram of a simple alternating-current dynamo; *b*, diagram of the same dynamo when the armature has turned one half rotation farther round and is going away from you while x is at the bottom and is coming toward you, the current is going out through B and in through A (Fig. 297, b). The current has alternated or changed its direction through the external, or outer, circuit.

---

[1] *External* (eks tur′nl): on the outside.

Commercial alternating-current dynamos for generating large currents use electromagnets for their magnetic fields instead of bar magnets. Electromagnets have many coils instead of only one loop as in Fig. 297, a and b. In some types the coils that make up the magnetic field rotate, but the coils in which the current is generated do not.

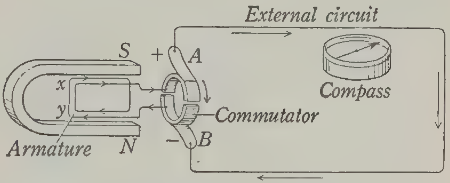

FIG. 298. DIAGRAM OF A SIMPLE DIRECT-CURRENT DYNAMO

How is it both like and unlike the simple alternating-current dynamo (Fig. 297)?

*Direct-current dynamos are similar to alternating-current dynamos. Instead of having slip rings like A.C. (alternating current) dynamos, D.C. (direct current) dynamos have one ring, which is cut into two or more parts. This ring is called a *commutator*. The commutator rotates, but the brushes do not. The commutator in Fig. 298 is a copper ring cut into two equal parts with insulating material between. The two ends of the coil are attached each to half the commutator. When the current is induced in the loop of the armature marked x, so that it flows toward the commutator, it flows out through brush A and in through brush B. When the armature rotates halfway round from its position in Fig. 298, the current in the coil has alternated and is now flowing through y toward the commutator. But y now makes contact with brush A, so that the current still goes out through *A* and comes in through *B* as before. Thus the commutator keeps the current always flowing in the same direction through the external circuit.

†The armatures of dynamos are sometimes turned by steam or gas engines. Thus the chemical energy of the fuel is transformed (see page 121) into heat energy, the heat energy into mechanical energy of the moving armature, and the mechanical energy into electrical energy. Occasionally in places where winds are strong and steady, the mechanical energy of wind is used to turn windmills, and these turn the armatures of dynamos. More frequently, however, the armatures of dynamos are turned by water power (see frontispiece). Water above a falls possesses potential energy (see page 120). This water is led down through pipes to water turbines (Fig. 35, p. 67) in a power house. These turbines turn the armatures of dynamos.

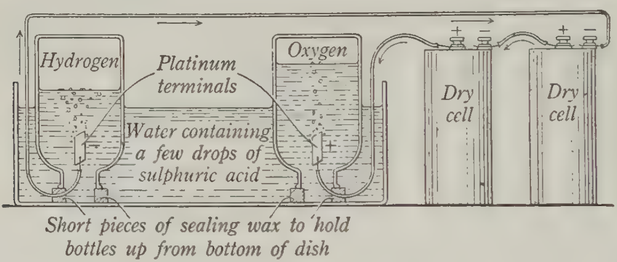
Hydrogen
Platinum terminals
Oxygen
Water containing a few drops of sulphuric acid
Dry cell
Dry cell
+
−
+
−
+
−
Short pieces of sealing wax to hold bottles up from bottom of dish

FIG. 299. BREAKING WATER INTO OXYGEN AND HYDROGEN BY USE OF A DIRECT CURRENT

339. †Electrolysis. *Electrolysis* is the process of breaking up a chemical compound into its parts by sending an electrical current through it. Thus, if a direct current of electricity is sent through water which is made a good conductor by adding to it a little sulphuric acid (Fig. 299), bubbles of hydrogen gas form on the – terminal and bubbles of oxygen gas on the + terminal.

Special Report. Can you explain why twice as much hydrogen as oxygen results from the electrolysis of water?

†We call this process the electrolysis of water; that is, the electrolysis of water is the breaking up of the chemical compound water into its parts, the elements oxygen and hydrogen, by electricity. Electrolysis is used in many industries and in all kinds of plating with metals, such as silver, gold, and copper (as in the following experiment).

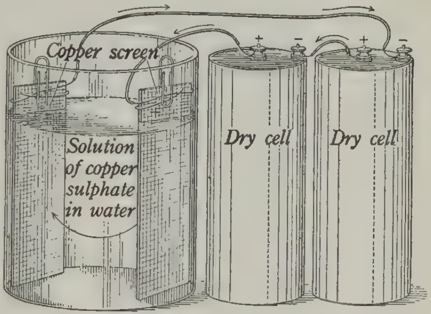

FIG. 300. USING DIRECT CURRENT TO PLATE METALS

Connect into the circuit a clean silver coin in place of the copper screen marked – (the one at the left). What happens to the coin?

340. Electroplating. *Experiment 73.* How can copper be plated with copper by electrolysis? Dissolve some blue vitriol (copper sulphate) in water. Attach two pieces of copper screen to wires connected with two dry cells in series (Fig. 300). Allow the current to pass through the solution for an hour. What changes can you see in the two pieces of screen? What conclusions do you make from the experiment?

†The metal which is deposited, or plated, upon another metal by electrolysis is very pure. Pure copper is obtained by the method illustrated in Experiment 73, from impure[1]

---

[1] *Impure* (im piur′): not pure.

copper bars (Fig. 182, p. 320). The bars of impure copper, just as they are produced from the copper ores, are hung in a tank containing copper sulphate solution. These bars are connected with the conductor leading from the plus pole of a source of direct current. Thin sheets of pure copper are also hung in the tank of copper sulphate solution. These are attached to the wire leading from the minus pole of the source of current. The copper is carried by the current from the copper bar through the copper sulphate and deposited evenly upon the sheets of pure copper. The substances which made the copper bar impure settle to the bottom of the tank.

Why is direct current used for electrolysis instead of alternating current?

341. Electrotyping. *Experiment 74.*[1] How is electrotyping done? With a *very soft pencil* draw a broad letter on a visiting card. Thread a fine copper wire from the minus terminal of the battery through the graphite[2] letter on a hard stiff card, so that the wire makes contact with the letter in at least four places. Be sure that the bare wire makes a good contact with the graphite. Complete the circuit as in Fig. 301. Let the current pass through the circuit for two hours. If you are careful you can remove the copper letter from the card.

†The plates from which this book were printed were made in the same manner as the letter which you just copperplated. After the page of type is set up a wax impression of the page of type is made. Before the type is stamped into the wax, the wax has finely powdered graphite brushed over it; this keeps the wax from sticking to

---

[1] This experiment was suggested by Dr. W. A. Gorton.

[2] The "lead" of a lead pencil is not made of lead, but of graphite, a form of carbon similar to coal.

the type. The graphite, which is a very good conductor of electricity, sticks to the wax and makes the face of the impression a good conductor; wax would not be a good conductor. The impression is connected with the minus terminal from a source of direct current and is immersed in a solution of copper sulphate. A bar of copper is connected to the positive terminal. A layer of pure copper is carried by the current to the graphite and deposited upon it in a thin layer. When the copper plate on the graphite is thick enough the wax impression and its copper plate is removed from the copper sulphate. The copper plate is separated from the wax and given a metal backing for greater strength. It is then ready for printing.

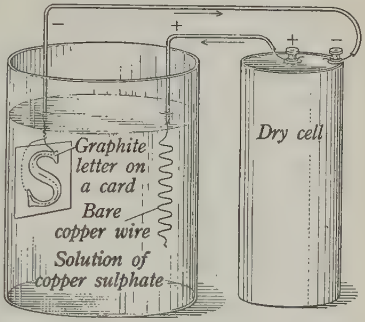

FIG. 301. USING DIRECT CURRENT TO PLATE TYPE WITH COPPER

Would this experiment be as successful if you exchanged the places of the type and the copper wire in the copper sulphate solution? Explain

Why is the wax impression connected with the minus terminal instead of with the plus terminal?

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. Electrical energy in the form of electrical currents is usually obtained from electrical ---- and ----.

2. Electrical cells make electrical energy transform electrical energy to chemical energy transform mechanical energy to electrical energy transform chemical energy to electrical energy transform electrical energy to mechanical energy.

3. Select from the following list of terms the one that does not belong with the rest: dynamo magnetic lines of force magnet armature slip rings dry cell brushes rotation complete circuit.

4. Select from the following list of terms the one that does not belong with the rest: zinc strip chemical action positive plate negative plate copper plate rotation complete circuit conductor.

5. The dry cell contains no liquid.

6. When an electrical cell is used continuously, its current finally becomes weaker because its voltage becomes weaker.

7. When the armature of a dynamo rotates, electrical pressure is produced which forces an electrical ____through the circuit.

8. An alternating-current dynamo is equipped with a commutator.

9. A dynamo transforms mechanical energy into electrical energy produces electrical energy transforms chemical energy into mechanical energy transforms chemical energy into electrical energy transforms mechanical energy into chemical energy.

CHAPTER XXXI

ELECTRICITY IN THE HOME

Some Questions this Chapter Answers

What are some uses of electricity in the home? For what purposes are electrical transformers used? How is electricity brought into the house? What purposes are served by switches and fuses? How does one read an electric meter? Are some of the more common electrical appliances expensive to use? How are lamps and appliances connected into the electric circuit? How is electrical energy transformed into light energy in the electric circuit? How does the electric bell operate?

342. *Increasing use of electrical energy. Not many years ago electricity found little use in homes. After people began to use electric lamps in place of candles, kerosene lamps, and gas lamps, other electrical appliances[1] and conveniences began to find a place in the home. The electric iron began to take the place of the old-fashioned flatiron, the vacuum cleaner (see page 29) did much of the work formerly done by the broom, heating devices such as electric stoves, toasters, and curling irons made their appearance, and small motors began to be used for sewing machines, washing machines, fans, and for a variety of uses in the kitchen (Fig. 302).

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[1] *Appliance* (ap pli′ance): a device or tool.

The use of electrical appliances is rapidly spreading because it is becoming more and more easy to get electrical service. Great power plants (see frontispiece) are sending their lines into the country districts. Where commercial electrical service is not yet obtainable, people are installing their own power plants, consisting of a dynamo run by a water turbine (see page 66) or by a gasoline or steam engine.

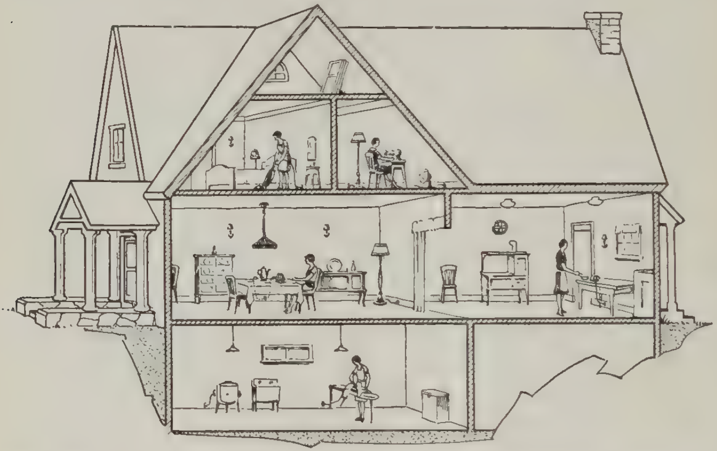

FIG. 302. MANY ELECTRICAL MACHINES AND DEVICES ARE FOUND IN THE MODERN HOME

How many electrical devices for the home can you name besides these shown in the picture?

343. †Transformers. Whenever alternating current is generated in great amounts from water power it is usually produced at the falls a long distance from where it is to be used (Fig. 303). It is sent from the power houses through wires. Some of this electrical energy is transformed into heat energy in the wires and is lost on the way. Less electrical energy is wasted by being transformed into heat if a small current is sent at high pressure (E.M.F., p. 543) than if a large current were sent at low pressure. When the alternating current is generated by the dynamos in the power house, therefore, it is sent through transformers which *raise* the E.M.F. and reduce the current. Sometimes the electrical pressure in long-distance power lines may be even as great as 220,000 volts.

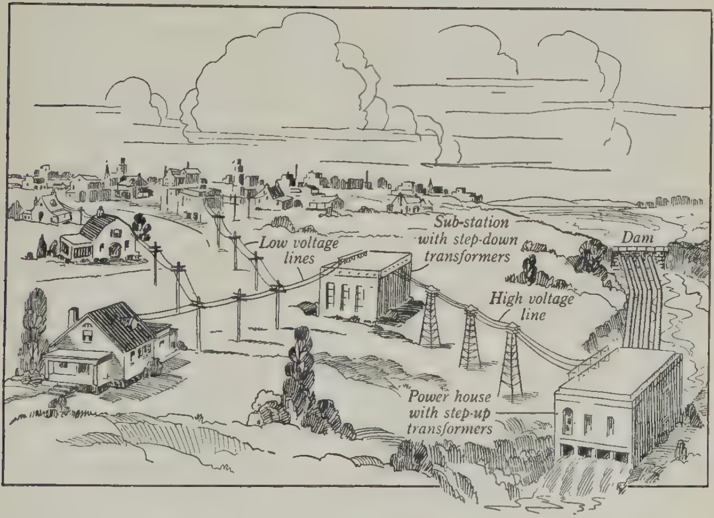

FIG. 303. FROM POWER HOUSE TO HOME

Can you show that electricity is secured indirectly from the sun?

†Electric currents cannot be sent into houses at high pressures without danger; therefore they are sent from the power lines through transformers, which *reduce* the pressure to a safe number of volts and at the same time increase the current. The pressure in house lines is usually 110 volts.

344. *The electric circuit in the house. If you examine the walls of the basement, attic, or back porch of your house you can see where the electric current enters from the service wire outside. You will notice that there are two wires, one for the current to enter the house and the other for it to leave the house, for, of course, no current would flow through the wires in the house unless the circuit were complete (see page 549). Just after they enter the house the two wires pass into an iron box. This box contains a switch and two fuses, one for each wire.

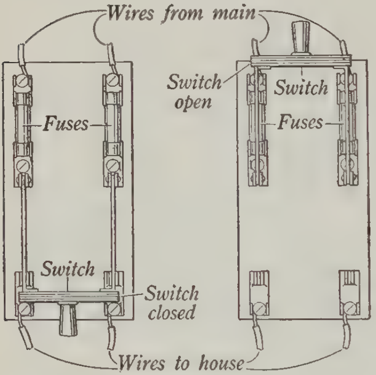

FIG. 304. THE ELECTRIC SWITCH

The switch is a convenient means of completing or breaking the circuit. At the left is shown the house switch closed and at the right it is open. Note the fuses. Why are they there? Why is the switch handle of hard rubber rather than of copper?

345. Switches and fuses. The switch completes or breaks an electric current. When the switch is down (Fig. 304, left), the circuit, or path, is complete and the current can flow; but when the switch is pulled up (Fig. 304, right), the circuit is broken and no current can flow through it. The switch acts like a drawbridge (Fig. 360, p. 653): when a drawbridge is open the traffic across it is stopped.

The main house switch is a safety device. Whenever anything is wrong with the electric service in the house or whenever the electricians[1] want to make any changes in wiring, they first open the house switch so that no current can flow into the house while they are working.

---

[1] *Electrician* (e lek trish′un): one who works with electrical appliances, materials, or currents.

Experiment 75. Does electrical friction, or resistance, produce heat? Short-circuit a cell by connecting a small copper wire across the terminals of the cell (Fig. 305). Does the wire get hot?

*The fuse is another safety device. We learned in Chapter XXX that when an electric current travels through a circuit it has electrical friction, or resistance. Mechanical friction produces heat; so does electrical friction, or resistance.

†Some kinds of conductors have greater resistance than others. Good conductors have small, or low, resistances; poor conductors have big, or high, resistances. An electric current passing through a conductor that has a low resistance does not produce much heat, but the same electric current passing through a conductor that has a high resistance produces much heat. Fuse wires have bigger resistances than the copper wire used in the house circuit; therefore fuse wires are made hotter by the current than are the copper wires. They also melt at a lower temperature than the copper wire.

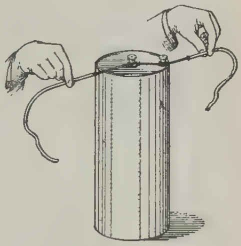

FIG. 305. SHORT-CIRCUITING A CELL

The current always seeks the easiest path from one terminal to the other

Special Report. Examine the wiring in your home. Locate the fuse box, the house switch, and the fuses. Make a diagram of these devices, showing how the wires enter and leave them.

Experiment 76. How do fuses protect the house? Connect a dry cell with a double knife switch, two short pieces of fine fuse wire, and several feet of copper wire as in Fig. 306, *a*. This represents the wiring in a house. The short copper wires from the cell are service wires, the switch and the pieces of fuse represent the arrangement shown in Fig. 304, and the long copper wire represents the wiring within the house. The compass is used to indicate when current is flowing in the circuit. Complete the circuit by closing (pushing down) the switch. Does the compass show that current is flowing through the circuit? Open the switch again. Short-circuit the house-wiring by attaching a piece of copper wire across the house circuit as in Fig. 306, *b*. Be sure that your short circuit makes good contact with the main circuit. Complete the circuit by pushing down the switch. What happens? Does the current still flow in the circuit? Answer with a complete sentence the question with which this experiment begins.

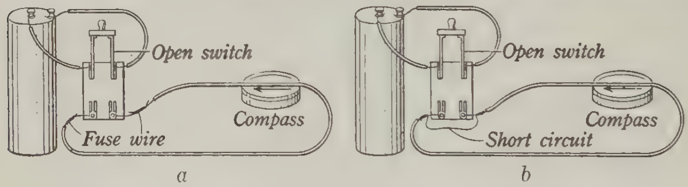

FIG. 306. MAKING A SHORT CIRCUIT

a, diagram of a simple electric circuit; *b*, the same, short-circuited. Is the current flowing in these two diagrams? Explain

*House fuses are usually of the type shown in Fig. 307. They are usually made to carry currents up to ten or fifteen amperes (see page 543). The number is stamped on the fuse. The fuse plug fits into a socket as does an electric lamp. The fuse wire completes the circuit as in Experiment 76 by connecting the side with the bottom of the socket. If too much current is being used from the circuit or if a short circuit is made anywhere in the house circuit, the heat produced in the wires may be very great. Without some safety device the wires might become hot enough to set fire to the house. But the fuse wire gets hot faster than the copper wire and fuses, or melts, at a lower temperature; it therefore fuses before the rest of the wire gets hot enough to do any damage. When it fuses it breaks the circuit and stops the flow of current just as if you opened the switch. When the trouble in the circuit has been repaired, another fuse is put into the socket, and the circuit is the same as before the fuse was melted.

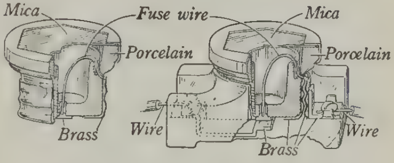

FIG. 307. DIAGRAM OF FUSE PLUG

Can you trace the circuit from one wire connected to the socket through the fuse to the other wire connected with the socket? Why is not the fuse plug made all of brass instead of being made partly of porcelain?

Sometimes when a fuse "blows," or melts, people remove the burned-out fuse plug and place a nickel or a penny in the socket. The coin completes the circuit just as the fuse wire did, by touching the metal at the bottom and the side of the socket. *This is a dangerous thing to do*, because putting in the coin has not removed the trouble in the house circuit: it merely has removed the protection which a fuse would give. Whenever a fuse melts, the safe thing to do is to report the trouble to the electric company or to consult an electrician unless you know exactly what is wrong and can make the repair yourself.

346. †The electric meter. After the wires leave the switch they go to the electric meter. This meter registers the amount of electrical energy which has been used. Electrical energy is measured in kilowatt-hours. The number of volts of pressure multiplied by the number of amperes of current which have flowed, multiplied by the number of hours the current has been flowing gives the watt-hours of energy used. Since 1000 watt-hours equal a kilowatt-hour, we must divide the number of watt-hours by 1000 to find the number of kilowatt-hours. For example, if a pressure of 110 volts sends a current of 10 amperes through the circuit for two hours, the number of watt-hours of energy used would be $110 \times 10 \times 2 = 2200$ watt-hours. The number of kilowatt-hours would be 2200 divided by 1000, which would be 2.2 kilowatt-hours. If power costs 8 cents per kilowatt-hour, the bill would be $2.2 \times 8 = 17.6$ cents.

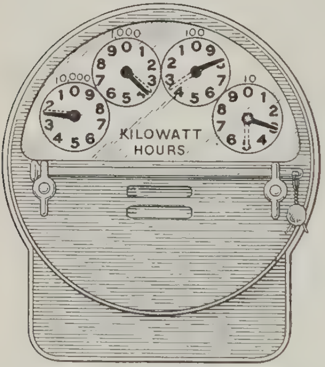

Fig. 308. The Dials of an Electric Meter

†In Fig. 308 the dotted lines show the positions of the hands on the dials[1] when the meter was last read. The reading was then 2335 (kilowatt-hours). What is the reading now? What is the bill at 13 cents per kilowatt-hour?

Circuits branch off to various parts of the house from the two wires which leave the meter. The wires running inside the walls are inclosed in metal tubes for better protection from fire.

347. *An outlet or socket is like an open switch. Outlets and sockets are installed at convenient places in the house to provide current for various electrical appliances. Two wires lead to every socket (Fig. 309). When a lamp or a plug is inserted in the socket, the circuit is completed through the lamp or appliance connected with the plug. When the circuit is completed, the current comes to the socket on one wire and leaves on the other. Cord such as is used to connect a plug with a floor lamp or a table lamp, a vacuum sweeper, or other electrical appliance,

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[1] *Dial* (di′al): a circular face marked off for measuring, as the dial of a watch.

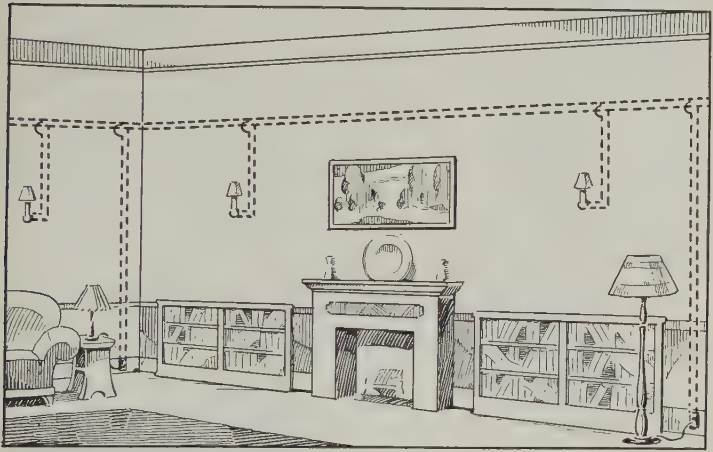

FIG. 309. A ROOM CIRCUIT

Electric lamps in houses are connected in parallel, that is, across the wires, with one terminal of the lamp connected with each supply wire, and not with both terminals of the lamp connected with the same supply wire. What is the advantage of connecting them in this way?

appears to contain only a single wire. If you remove the outer cloth insulation from this flexible cord, however, you will discover *two* wires inside leading to the lamp or appliance, one to carry the current from the socket to the lamp or appliance, the other to carry the current back to the socket. Lamps and appliances are connected in parallel (Fig. 309), just as the cells in Fig. 289, p. 549.

348. Electrical appliances. Appliances such as the electric washing machine, the electric sewing machine, and the vacuum cleaner make use of small motors to transform the electrical energy into mechanical energy. Where electric power costs 10 cents per kilowatt-hour, these electric motors will do their work for an entire hour for about 2½ cents for the washing-machine motor, ¾ of a cent for the sewing-machine motor, and 1¾ cents for the vacuum cleaner. The action of the electric motor is explained in Chapter XXXV.

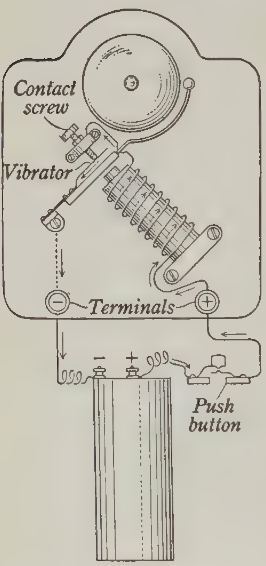

FIG. 310. THE ELECTRIC DOORBELL

When the push button is pressed down, the circuit is completed and the current flows through the circuit in the direction of the arrows. In what ways is a push button like a switch (Fig. 304, p. 566)? In what ways is it different?

Electrical appliances such as the flatiron, heater, toaster, and stove transform electrical energy into heat energy. The heating elements of each of these devices are coils of wire. In passing through these coils the current produces enough heat to make the coils of wire white-hot. Electric heating is too expensive to be used for a whole house; a radiant electric heater costs 6 cents per hour when electricity costs 10 cents per kilowatt-hour. At the same rate, it costs 5½ cents per hour to run an electric coffee percolator (Fig. 178, p. 312), 6 cents for a table stove, 6 cents for a waffle iron, and 5 cents for a toaster. These devices, however, are not usually operated steadily for an hour.

349. *Electrical energy transformed into heat and light energy in electric lamps. An electric lamp works on the same principle as the electric heater. A fine wire made of tungsten is attached (usually in the form of a coil) to a support in the lamp globe. This wire is called the filament of the lamp. When current passes through this filament its high resistance produces enough heat to cause it to become incandescent and to produce a bright white light.

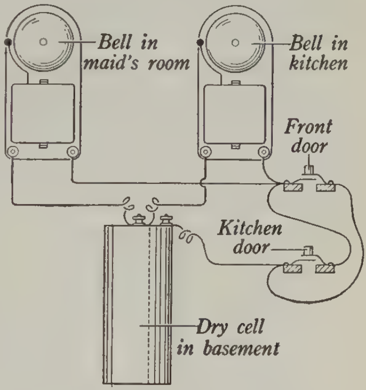

FIG. 311. A DOORBELL CIRCUIT

Are the push buttons connected in series or in parallel (see page 549)? Why?

350. †The electric doorbell. In the electric doorbell (Fig. 310) the circuit leads first from the terminal to the electromagnet, thence to the bottom of the little post which holds up the contact screw. (Note that the contact screw is insulated (see page 550) at the bottom of the metal frame.) The circuit then leads across the contact screw to the iron vibrator, which touches the contact screw, and from the vibrator through the metal frame. The metal frame serves as a wire to conduct the current to the other terminal of the bell.

†As soon as the top of the push button is pressed down, the circuit through the bell is complete. The electromagnet becomes magnetized and attracts the iron vibrator to it, pulling the vibrator away from the contact screw. As soon as the vibrator leaves the contact screw the

circuit is broken and the current stops flowing through the electromagnet. The electromagnet therefore loses its magnetism and no longer attracts the vibrator. The spring on the vibrator then pushes the vibrator back so that it again touches the contact screw. Immediately the circuit is complete again, and the electromagnet again attracts the armature, breaking the circuit. This action keeps repeating as long as the push button is held down.

Experiment 77. Would the bell ring if you reversed the current; that is, sent it through in the opposite direction? Try it. What happens to the electromagnet when you reverse the current through it? Test it with a compass to find out what happens to it. Answer each of these questions with a complete sentence.

Fig. 311 shows how a push button at each of two doors will ring two bells at different places. Are the bells connected in series or in parallel (see page 549)? Why?

A private hospital having six rooms for patients is equipped with a push button in each room. Diagram a system of connections so that any one of the push buttons will ring the same bell in the head nurse's room.

Diagram a system of connections having two bells and two push buttons connected to the same battery, so arranged that one bell will be rung by one push button, and the other bell by the other button. Make another diagram showing how each push button can be connected so as to ring both bells at once.

What changes would you have to make in an electric bell to make it a single-stroke bell instead of a vibrating bell?

†A battery of two dry cells connected in series is frequently used for doorbells. Dry cells are not especially

satisfactory for this purpose, because their chemical energy is used up after a few months and they have to be replaced. For this reason, in houses which are equipped with electric current the house-service wires frequently have a small transformer connected with them to take the place of the battery of dry cells in ringing the doorbell. The price of the bell-ringing transformer is much greater than the price of two dry cells, but through a long period of use the transformer is cheaper, because some types can be run continuously for ten hours at a cost of one cent. The transformer is also much more convenient than the dry cells for this purpose, because it needs no attention and will last for many years.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. Select from the following list of terms the one that does not belong with the rest: **vacuum sweeper** **electric toaster** **electric washing machine** **electric sewing machine** **electric fan.**
2. Electrical service to a house requires only one wire.
3. A fuse wire is a device designed to aid in fire prevention.
4. A fuse is a good insulator of electricity.
5. Lamps are usually connected in series in a circuit, so that when one is turned off the current may still flow through the rest.
6. An electric lamp transforms **electrical energy to chemical and mechanical energy** **light energy to heat and electrical energy** **heat energy to electrical and mechanical energy** **light energy to heat and mechanical energy** **electrical energy to heat and light energy.**

7. Select from the following terms the one that does not belong with the rest: electric lamp electric curling iron electric washing machine electric toaster electric stove electric table stove electric warming pad electric heater.

8. The two wires in a lamp cord are carefully insulated from each other to prevent a short circuit.

SCIENTIFIC PUZZLES AND GAMES

Which of the five statements that follow each of the two problems stated here would a carefully trained scientist choose as best? Justify your answer by stating one or more of the scientific attitudes (see pages 8–10).

Problem 1. A magazine has printed a signed letter from a famous ball-player who writes that a certain patent medicine has done wonders for him and will cure anybody who has the same illness that he had.

a. The medicine has no merit whatever.
b. The ball-player's cure may have been due to something else besides the medicine.
c. The medicine may be helpful in certain cases.
d. The medicine doubtless has great merit.
e. The ball-player may have sold his signature without ever having taken the medicine.

Problem 2. Many people believe that bald-headedness, that is, absence of hair, indicates that the bald-headed person is of superior intelligence.

a. The belief is probably sound.
b. The belief is undoubtedly sound, since many college professors and preachers are bald-headed.
c. The belief might be sound, but it probably is not.
d. The belief could not possibly be sound.
e. The belief is not sound, because not all intelligent men are bald-headed and not all stupid men have good heads of hair.

UNIT XIII. COMMUNICATION

CHAPTER XXXII

SOUND AND ELECTRICITY IN COMMUNICATION AND ENJOYMENT

Some Questions this Chapter Answers

How are sounds produced? What carries sounds from one place to another? How do sounds travel in air? In what ways do sounds differ from each other? Why? What are the characteristics of some of the common types of musical instruments? How are people able to speak and sing? How do we hear? How should one take care of his hearing? What are echoes? To whom does the credit for a great invention belong? How does the telegraph operate? How does the telephone operate? What are some important facts about the radio?

351. †How sounds are produced. If you stretch a rubber band between your hands and have somebody pull the band in the middle, then let go of it, you will observe two phenomena: you will hear a musical sound given off by the band and you will see that the middle of the band is moving back and forth, or vibrating (Fig. 312, *A*). If one end of a knitting needle is stuck into a board (Fig. 312, *B*), and if you then bend and release the free end, you will again observe the same phenomena that you observed with the rubber band. You will hear a humming sound and will see that the free end of the needle is vibrating.

Experiment 78. Strike the end of a tuning fork. Quickly stick the end of the fork into water. Do you observe any phenomena which indicate that the fork is vibrating? Strike the fork again and touch the end lightly against your ear. Do you observe the same phenomena that you observed with the rubber band and the needle (Fig. 312)?

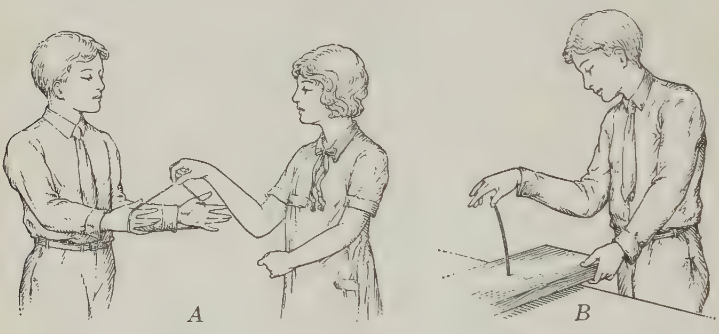

FIG. 312. SOUNDS ARE PRODUCED BY VIBRATING BODIES

When the rubber band (*A*) and the knitting needle (*B*) are released, they will vibrate and thus produce a humming sound

*If you were to continue your experiments, you would find that whenever a sound is being made, the body that is producing the sound is in vibration.

352. *What carries sound? Suppose that two balloons carrying passengers were to rise together at the same rate of speed, having started close enough together so that the passengers in one balloon could talk with those in the other. They would note that as they rose the sounds of their voices would become less loud. If the balloons should remain at the same distance from one another and should continue to rise, it would be constantly more and more difficult for the sounds from one balloon to be heard in the other. As the air became less dense the sounds would become fainter. It has been proved in the laboratory that sounds will travel scarcely at all in a partial vacuum. It is thought that if a perfect vacuum could be formed, no sounds could travel through it.

*Have you ever been diving or swimming under water while somebody struck two stones together under the surface of the water? If so, you know from experience that water carries sound very well; in fact, water transmits or carries sound to the ear better than the air. Solids, such as wood and iron, transmit sound even better than water does.

> Can you summarize the most important facts given in the last two paragraphs by putting one word in the blank in the following sentence?
>
> Sounds are carried by ----.
>
> Walls which are filled with loose sawdust or which have air spaces between them are good "deadeners" of sound. Why? Why did the Indians and the pioneers place their ears against the ground to find out whether horses were approaching?

353. *How sounds travel in air. If you drop a stone into a pond, tiny waves are formed which follow each other swiftly along the surface of the water to the bank. Similarly, whenever a body vibrates, it produces air waves (Fig. 313). These air waves follow each other away from the vibrating body in much the same way as the water waves.

> If the bell in Fig. 313 makes eighty vibrations per second, how many waves will it send out in a second? How many vibrations will reach each of the ears each second?

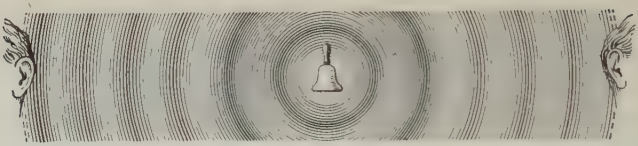

FIG. 313. SOUND WAVES TRAVEL THROUGH THE AIR IN ALL DIRECTIONS FROM THE SOUNDING BODY

Sounds are more readily heard at a distance if sent out directly toward the hearer. For this reason the cheer leader uses a megaphone (Fig. 314) and points it directly toward the people in the cheering section when he wants them to hear his directions. For the same reasons speaking tubes are installed between the pilot house and the engine room of steamships and between the front door and the various apartments in apartment houses.

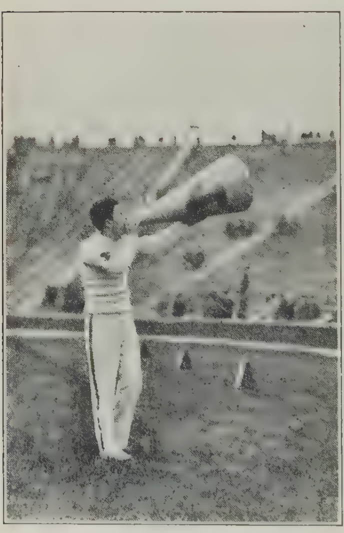

FIG. 314. DIRECTING SOUND WAVES

If the people held the small ends of megaphones to their ears and pointed the large ends toward the leader they could hear better than if neither the leader nor they used megaphones. Why is this statement true?

Project. To make a tin-can telephone. Fig. 315, at the top of the next page, shows how it is made and used. Why must the string be stretched tightly between the cans while the telephone is being used? Why is each girl careful to grasp the can near the top rather than by the bottom? Can you explain how a tin-can telephone operates?

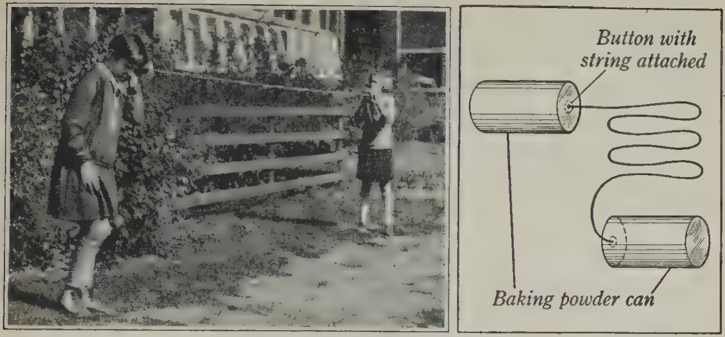

FIG. 315. A TIN-CAN TELEPHONE AND A DIAGRAM OF ITS PARTS
Why is wire better than string for this purpose?

354. †Speed and loudness of sound. Have you ever seen the steam jet from a distant locomotive or factory whistle before you heard the sound of the whistle? A few moments later the sound reached you. At ordinary temperatures sound travels about eleven hundred feet per second in air, faster in water, and still faster in solids such as wood, metal, or stone. It travels somewhat slower at lower temperatures than at higher temperatures.

> If you saw a flash of lightning a mile away, about how long should you have to wait before you would hear the thunder? About how many miles a minute does sound travel? Ordinarily would thunder from a lightning flash a mile away be heard sooner after the flash in summer than in early spring or late fall? Why?

*When you hear a band playing in the distance, you may at first hear only the large drum and occasional strains from some of the horns. You know that the whole band is playing, but you are too far away to hear it all. As you approach the band you hear it more plainly. You now hear some of the smaller instruments which you did not hear at first. Sounds differ from each other in loudness. The nearer you are to the vibrating body, the louder the sound.

355. †Sounds differ in pitch and quality. The lowest note (that is, the note having the lowest pitch) on a piano vibrates 27 times per second, and the highest note about 4150 times per second. The greater the number of vibrations per second, the higher the pitch. If a body is vibrating too fast or too slowly, however, we cannot hear it. Most people cannot hear any sounds from a body that is vibrating more than 30,000 times per second or less than 16 times per second.

When machinery is first started the sound is at a lower pitch than after the machinery is going at full speed. Why? Why is the sound of the wings of a flying bird so much lower in pitch than that of the wings of a flying insect, such as the fly or the mosquito?

†Some sounds, such as the tones from musical instruments, are pleasing; others, like Halloween noise-makers, are not. Musical tones are produced when the vibrating body sends out regular vibrations to the ear; noises are produced when the vibrating body sends out irregular vibrations to the ear. If a group of people are singing together, the effect is pleasing because the vibrations which strike the ear are regular; but if the same group begin to shout in different keys, the effect is a noise, because the vibrations striking the ear are irregular. We know the voices of our friends. We recognize the tones of a violin from those of the cornet or piano, even though they may be sounding the same note. These differences make up the *quality* of the sound. The quality may be good in the case of an expensive violin and poor in the case of a cheap one. Differences in the quality of sounds are due not only

to the regularity or irregularity of the vibrations but also to the shape and the materials of the instruments.

Experiment 79. Examine any stringed instrument, such as a violin. Note the size of the different strings. Are the strings that produce the low notes bigger than those that produce the high notes? Make the strings tighter and see whether the notes produced by them are lower or higher. Make the vibrating part of the string shorter by pressing it down firmly against the finger board on the neck of the instrument.

In the following statements can you select the word or phrase which makes the correct meaning?

The greater the tension[1] on the string, **the higher the lower the more pleasing the louder the softer** the note.

The shorter the string, **the higher the lower the more pleasing the louder the softer** the note.

356. Musical instruments. Probably the first musical instrument man used was a drum. At first this probably consisted of a stump or a log pounded with a club. Later man learned how to make better drums by stretching skins over hollow logs. Thus almost all primitive peoples have tom-toms or war drums of some sort; and in our orchestras we have bass drums, kettledrums, and snare-drums, all scientifically made and all requiring considerable skill and knowledge of music to play.

Drums can hardly be called musical instruments, since, with the exception of the kettledrum, they are used not for tones but for time (that is, the beat). When a drum is beaten, not only does the membrane of the drum vibrate but also its walls and the air confined within. Thus the sound is made louder because more matter is in vibration.

---

[1] *Tension* (ten′shun): the condition of being tightly stretched.

*Instruments which are played by being struck (for example, the drum) are called *percussion instruments.* Familiar percussion instruments are the piano and the xylophone. In the piano the strings are caused to vibrate by being struck with felt hammers; in the xylophone, bars of wood or metal are caused to vibrate by being struck with mallets.

*Instruments which produce music when they are blown are called *wind instruments.* There are several different types of wind instruments. In the bugle, the cornet, the trombone, and the like the lips of the player vibrate, producing the sound. This sound is made louder by the instrument and by the air column in the instrument. With instruments such as the flute and all whistles the player blows an air jet across the mouth of the instrument, producing regular vibrations of the air column in the instrument. With instruments like the saxophone and the clarinet a reed inside the piece for the mouth controls the vibrations.

How many other wind instruments can you name? Which of the three types of wind instruments given above is each like?

*Instruments which produce music from vibrating strings are called *stringed instruments.* The violin, the cello, the guitar, and the banjo are familiar examples. The sound produced by the vibrating strings is made louder both by the wood of the body and by the air column inside the body.

How many other stringed instruments can you name? In which of the three big classes of instruments here given would you place bells? the jew's-harp?

Special Reports. Describe the Wurlitzer organ; the pipe organ; a symphony orchestra.

*In 1876 Thomas Edison invented the commercial phonograph. This invention has made possible the recording and reproducing of the world's greatest music played and sung by the world's greatest musicians. In making records the music is played or sung into a receiver which has an elastic disk. This disk vibrates in harmony with the music. A needle attached to the center of the disk vibrates against a wax cylinder or plate, making a path. A copper or gold copy is made of the wax record, and from the copper or gold record, called the "master" record, many copies, or records, are made on hard rubber or other material.

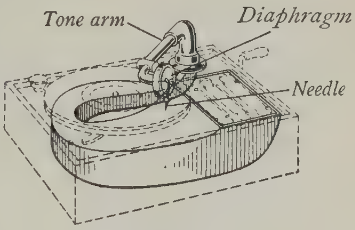

FIG. 316. DIAGRAM OF A PHONOGRAPH

This small phonograph, which is intended to be carried on vacation trips, has all the necessary parts of a big home phonograph

*When a record is played (Fig. 316), the needle travels in the path, and is made to vibrate like the needle that cut the original path in the wax record. The vibrations from the needle are carried to a diaphragm,[1] setting it into vibration also. These vibrations set up in the air the same vibrations as those of the original music, thus reproducing the original sounds.

*The player piano is made so that air pressure operates the keys. A partial vacuum is produced inside by an air pump operated by an electric motor or by one's feet. The greater pressure outside forces air through the holes in the music roll. This air current operates valves and levers (see page 134), and these control the keys.

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[1] *Diaphragm* (di'a fram): a thin vibrating disk or membrane.

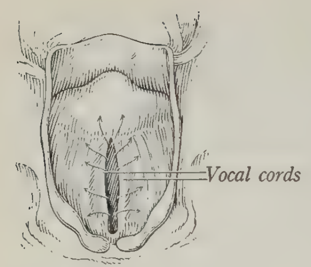

FIG. 317. THE HUMAN VOICE-PRODUCING ORGAN

When we are not breathing, the vocal cords touch each other and there is no opening between. When we breathe, the cords are much wider apart than they are in this figure, which shows the position they take in singing

357. *The human voice. Differences in the quality of people's voices are due chiefly to differences in the size and shape of the air passages in the nose, mouth, and throat, and to the position and length of the vocal cords (Fig. 317). As we speak or sing we change the position of the tongue and make other changes in the size and shape of the air passages. Some have naturally pleasing voices, and others have harsh voices. Usually it is possible to improve our speaking voices by speaking in a low tone, by speaking every syllable distinctly, and by never straining the voice in speaking or singing. Proper position of the body and good teeth are also important in good singing and speaking voices.

> Can you complete this statement by adding three words? Sounds differ from each other in ----, ----, and ----.

*The human voice-producing organ is located at the top of the windpipe in the throat, opposite the "Adam's apple." The air passes from the windpipe between the two vocal cords in puffs. These puffs of air cause the tightly stretched vocal cords (Fig. 317) to vibrate, producing a sound. The more tightly the vocal cords are stretched and the smaller the space between them, the higher the tone. The different tones produced by the cords are made into different words and syllables by changing the positions, and consequently changing the action, of the parts of the mouth and throat.

> Judging from their voices, which do you think have the longer vocal cords, women or men? From your study of the instrument in Experiment 79, p. 583, can you give two reasons why little children cannot sing in a deep voice?

358. *How we hear. The ears of animals and of people are shaped somewhat like a megaphone (Fig. 314, p. 580); that is, like a funnel with the larger end on the outside of the head. You have seen how dogs, cats, mules, and other animals are able to point the large end of the ear in the direction of the sound. Fig. 241, p. 463, shows the various parts of the human ear. The sound waves strike the outer ear, which directs them against the eardrum. The sound waves set the eardrum in vibration. These vibrations are carried by the little bones from the eardrum across the middle ear to the inner ear. The sensation is then carried to the brain by a special nerve. We really hear with our brains, because we have learned little by little, through experience, to interpret the meaning of the sounds which our ears report to our brains from our environment. Thus our brains learn to distinguish the voices of our friends from those of strangers, though our ears report one voice as readily as any other.

359. *Care of the ears. Our ears are of very great importance to us as a means of getting along successfully in our environment. We need good hearing in order to guard ourselves against approaching dangers which we may not see, to engage in conversation with our friends, and to enjoy music. Therefore it is necessary for us to take the best possible care of our ears.

*Here are some easy and sensible rules for the care of the ears:

1. Never shout directly into anybody else's ear or allow anybody to shout directly into yours. Why?
2. Never pinch your nose while you are blowing it. If you do you are liable to cause ear trouble by blowing germs into the middle ear through the tube connecting the inner ear with the throat. When you blow your nose, always hold your handkerchief just under the nose, and do not pinch it until you have finished blowing it.
3. If you have trouble with your nose or throat, consult a specialist at once. It is much easier to cure such troubles if they are treated at the beginning. Nose and throat troubles sometimes cause permanent deafness.
4. Never thrust a pencil, pin, or any other sharp-pointed object into your ear. You may injure the eardrum or the lining of the canal.

One can buy at most drug stores patent medicines that claim to be remedies for diseases of the ear. These state on their labels that they "relieve deafness and head noises." In certain types of magazines "eardrums" and other devices are advertised to relieve deafness. Such medicines and devices neither relieve deafness nor cure ear diseases; some of them may even do harm to the person who buys them at a high price with the hope of being cured. In all cases of ear trouble the only safe thing to do is to consult a physician; if possible, one who is an ear specialist.

360. *What are echoes? Have you ever made an echo by shouting toward a wall, a mountain, or a forest? The sound you made traveled to the wall, from which it was reflected back to you so that you could hear it. Such reflected sounds are called echoes. The ear is unable to distinguish between sounds which occur within less than one tenth of a second of each other. Thus sounds made in small rooms are reflected back in time to blend with the original sound. If the room is more than fifty-five feet from front to back, however, an echo is produced which interferes with the sounds being made in the front of the room. To prevent these echoes, hangings are often placed on the back walls.

> Why are echoes not reproduced within fifty-five feet from the reflecting surface? (Remember how far sound travels in one second.)

361. Invention of the telegraph, the telephone, and the radio. It is seldom that the credit for any important invention belongs entirely to one man. We are accustomed to hear that Morse invented the telegraph, that Bell invented the telephone, and that Marconi invented the wireless. These statements are not strictly true. It is true that Morse invented the first practical telegraph, Bell the first practical telephone, and Marconi the first practical radio. Every scientist who did important earlier experimenting with electricity, however, is entitled to some credit for every electrical device or machine that is invented later. It is not taking any credit away from the man who finally invents a practical machine to say that he has used the work of many earlier scientists as a foundation for his invention. He is entitled to great honor because he has been able to extend the work of other men. A great inventor is like a builder who is able to take a pile of material which one man has prepared, another pile of different material which another man has prepared, and so on with many different kinds of materials prepared by many different men, and, by adding materials of his own, to combine all into something new for all the world to use and enjoy.

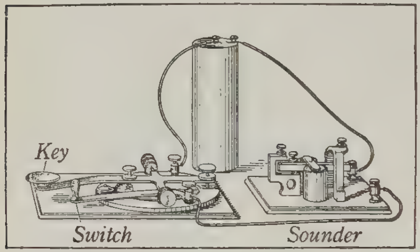

FIG. 318. A COMMERCIAL KEY AND SOUNDER

362. †The telegraph. Fig. 318 shows a commercial telegraph sounder and key. The key acts like an ordinary switch or like the push button for a doorbell. The armature[1] of the sounder is operated by an electromagnet (see page 553) and a spring. When the key is held down, the circuit is completed. Current then flows through the electromagnet, which attracts the iron bar on the armature, pulling it down with a sharp metallic sound. When the key is released, the spring on the key pushes it away from the metal frame of the key, breaking the circuit. The electromagnet at once loses its magnetism, and hence its attraction for the armature, which is then, by means of a string, pulled up with a dull sound against the metal screw of the sounder.

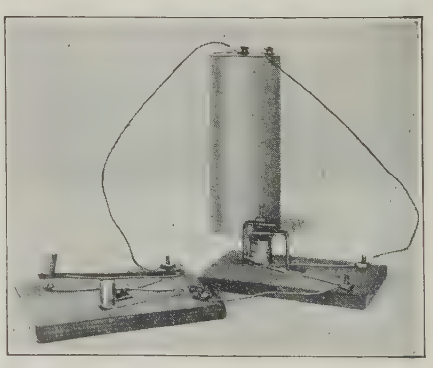

FIG. 319. A HOMEMADE TELEGRAPH KEY AND SOUNDER

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[1] This kind of armature is not like the armature of a dynamo (see page 556). It does not revolve, but moves back and forth or, in this case, up and down.

†The operator makes a dot by pushing the key down and releasing it as quickly as possible, thus first very quickly making or completing the circuit and then breaking it. The sharp sound made by the armature against the electromagnet is followed so quickly by the dull sound it makes against the screw of the sounder that the two sounds seem almost like one. The operator makes a dash by holding the key down an instant before releasing it.

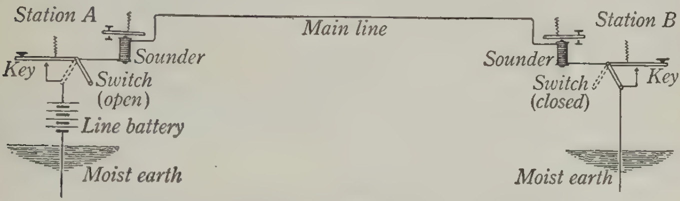


FIG. 320. DIAGRAM OF A COMPLETE TELEGRAPH LINE

The sharp sound of the armature against the electromagnet and the duller one against the screw are heard separately. Certain combinations of dots and dashes are used to represent numbers and letters.

> ***Project.*** To make a simple telegraph key and sounder. A boy in the seventh grade made the instruments (Fig. 319) with wire, screws, and strips of iron. The armature of the sounder is flexible. Can you make a set?

†A complete telegraph system in its simplest form is represented by Fig. 320. By grounding the wire at each station no return wire is needed, because the earth conducts the current between the two stations, completing the circuit. Both keys are kept closed so that current is constantly flowing in the circuit when no messages are being sent. When the operator at *A* wishes to send a message, he opens the switch, breaking the circuit. The cir-

cuit is completed again and current will again flow through the wire only when the operator pushes down the key. The electromagnets at both ends become magnetized at the same time. When the operator at *A* finishes, he closes his switch and the operator at *B* opens his switch to reply.

What would happen if either operator forgot to close his switch when he had finished sending? How many cells compose the battery shown in Fig. 320?

Special Report. Diagram a long-distance telegraph circuit with which relays are used. Explain the action of the relay.

363. *The telephone. When we telephone to our friends we can recognize their voices. From this fact we are likely to believe that sound waves travel through telephone wires from the speaker to the listener. But if we stop to think a moment we realize that it would be impossible to carry on telephone conversations, especially long-distance conversations, if we had to wait for the sound to pass through the wires. Telephone messages, like telegraph messages, are carried by electricity.

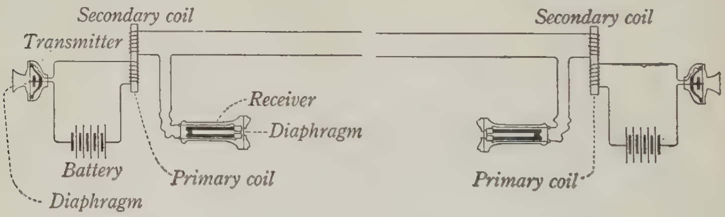


FIG. 321. DIAGRAM OF A TELEPHONE CIRCUIT

Fig. 321 shows a simple telephone circuit. Fig. 322 is a diagram of the telephone transmitter, and Fig. 323, a diagram of a telephone receiver. The diaphragm of the transmitter is a thin sheet of metal. This diaphragm is attached to a small box filled with carbon granules. You will see in Fig. 321 and in Fig. 322 that the current passes from the plus pole of the battery through the carbon granules in the transmitter, thence through the primary coil, and back to the minus pole of the battery. Current is flowing through this circuit all the time.

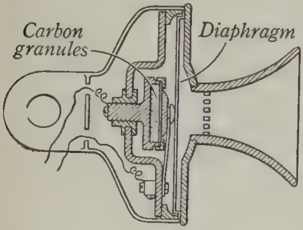


FIG. 322. DIAGRAM OF A TELEPHONE TRANSMITTER

Fig. 323 shows that the telephone receiver contains a permanent U-shaped steel magnet. On each end of this magnet is an electromagnet (see page 553) having many turns of fine wire wound round the iron core. These electromagnets are wound in opposite directions. The circuit through the receiver is connected with the secondary coil.

364. How the telephone operates. When a person speaks into the transmitter the sound waves set up by his voice make the diaphragm of the transmitter vibrate the same number of times per second as his vocal cords. When the sound wave strikes the diaphragm, it starts the diaphragm vibrating. Each time that the diaphragm moves toward the carbon granules, it presses the granules together. The current from the battery then flows more easily through the primary circuit, because the resistance of the granules is less. When the vibrating diaphragm

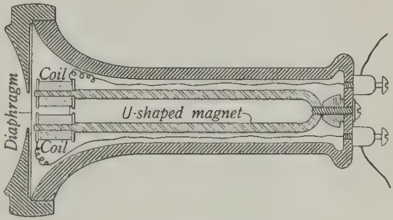


FIG. 323. DIAGRAM OF A TELEPHONE RECEIVER

moves away from the granules, the granules move farther apart. The current is then weaker through the primary circuit because the resistance of the granules is greater. The strengthening and weakening of the current through the primary makes the primary electromagnet first stronger and then weaker. The changing strength of the primary electromagnet induces alternating currents in the secondary coil. Thus a current is induced in one direction in the secondary circuit when the diaphragm of the transmitter moves toward the carbon granules, and in the opposite direction when the transmitter moves away from the granules.

When these induced alternating currents pass through the receiver at the other end of the secondary circuit, the electromagnets on the ends of the permanent magnet in the receiver are magnetized first in one direction and then in the other. These electromagnets therefore strengthen and weaken the permanent magnet. The changing magnetism of this magnet sets the diaphragm of the receiver vibrating in time with the diaphragm of the transmitter. The diaphragm of the receiver therefore sets up sound waves like those of the voice in the transmitter.

365. *Many of the principles of the telephone used by the radio. Many of the facts that we have already learned about electricity help us to understand radio. The transmitter sends out waves. These are similar to heat and light waves (see pages 164 and 597) and travel with the speed of light. When they strike the wires of the receiving set, they set up induced currents. These induced currents pass through the receiving set. In doing so they reproduce the sounds which went into the sending, or transmitting, set.

There are few modern devices which are being so often changed by new inventions as the radio, with the result that the latest model of radio today is likely to be out of date tomorrow.

> *Special Report.* Make a study of the latest model of a radio set which you can examine. Demonstrate before the class how to operate a radio set.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. Sounds are produced by matter in vibration.
2. Sounds travel **in air only in ether through a vacuum in matter only in liquids only in solids only in _ _ _ _ only.**
3. Sounds travel in waves from a body which is moving.
4. The sound of a church bell is louder when a person is a mile away than when he is **a half mile away a quarter of a mile away a hundred yards away two miles away in the church.**
5. Select from the following list of terms the one that does not belong with the rest: **kettledrum violin xylophone piano snare drum bass drum cymbals.**
6. Select from the following list of terms the one that does not belong with the rest: **bugle cornet saxophone piano trumpet tuba trombone flute whistle.**
7. Select from the following list of terms the one that does not belong with the rest: **violin bass viol cornet banjo mandolin ukulele guitar cello.**
8. The vocal cords produce sound in much the same way that sound is produced in a **xylophone piano ukulele bass drum saxophone.**
9. One would be most likely to be able to produce echoes if he were shouting **in a dense forest on a prairie into a barrel through a megaphone a few hundred yards from a cliff.**

UNIT XIV. LIGHT AND MAN'S USES OF IT

CHAPTER XXXIII

LIGHT IN EVERYDAY LIFE

Some Questions this Chapter Answers

What are the nature and the importance of light? What are luminous and nonluminous objects? What are transparent, translucent, and opaque objects? How do mirrors produce images? What is diffusion? Does light travel in straight lines or in curving lines? How are shadows formed? What is refraction? What causes the rainbow? What causes objects to be colored? What are some important facts about lighting the home with sunlight? What are some of the most important facts about candles, oil lamps, gas lamps, and electric lamps? What are some important facts to know about artificial lighting in the home? What are the important types of illumination in the home?

366. †Light a form of energy. Until a few hundred years ago it was thought that light was a special talent or ability of the eye. The eye was thought to seize upon objects with some sort of invisible means, and in some way to give an idea of the object. This theory seems foolish to us now, but nobody has even yet suggested one that accounts satisfactorily for *all* the phenomena of light. The great scientists are generally agreed, however, that light is a form of energy, and that it travels, like radiant heat and radio, by means of waves. Light, radiant heat, radio, and X-rays are *known* to travel at the same speed, about 186,300 miles per second.

†Without light and other similar waves which sunshine contains, there could be no life on the earth. With the aid of sunshine green plants manufacture starch and thus directly or indirectly produce all the food in the world. Sunshine, moreover, may kill the germs of disease (see page 83) and is essential to health and growth.

367. †Luminous and nonluminous objects. Luminous objects are those which give off light; nonluminous objects are those which do not, themselves, give off light, but which reflect more or less of the light which strikes them from luminous objects. The sun and other stars, lighted lamps, and fires are familiar examples of luminous objects; the moon, ourselves, and this book are examples of nonluminous objects.

Tell which of the following objects are luminous and which are nonluminous: Jupiter, glowworms and fireflies, the spiral nebula (Fig. 169, p. 290), a photograph, a diamond, a watch dial upon which one can read the time in the dark.

368. Transparent, translucent, and opaque objects. Transparent objects allow light to pass through them well enough so that one can see objects clearly through them; translucent objects allow some light to pass through them but not enough to permit one to see objects clearly through them; opaque objects do not allow light to pass through them, that is, one cannot see through them at all. Examples of transparent objects are water and glass, examples of translucent objects are frosted-glass and stained-glass windows, and examples of opaque objects are stones and boards.

> Classify the following objects as transparent, translucent, or opaque: metal lamp shades, air, a coin, a piece of paper held against the windowpane, a celluloid eye-shade, one's hand held against a bright lamp.

369. *Mirrors reflect images. Whenever light strikes an object some of the light is reflected, some is absorbed, and, if the object is transparent, some passes through the object. A mirror is any opaque object with a surface smooth enough to reflect the light in such a way as to show an image (picture) of objects that are in front of the surface. The light is reflected in straight lines from the mirror to the eye. The eye catches the image, which looks to be as far behind the mirror as the object is in front.

The first mirrors were pools of water (Fig. 324). Later men used plates of polished metal. Now we use glass coated with silver or with an alloy of tin and mercury.

> *Special Report.* Compare the following mirrors for likenesses and differences: an ordinary flat mirror, a round-backed automobile mirror, and a round-backed shaving mirror.

370. †Diffused light. When light is reflected from a rough surface it does not give an image, because the reflected light is scattered in all directions. Light thus reflected is called *diffused* light. When the sunlight passes through the air, some of it is diffused by the floating dust particles. This diffusing, or *diffusion*, of light causes the twilight after the sun has gone down. Explain.

> When the sun sets on the moon, darkness follows *instantly*. Explain.

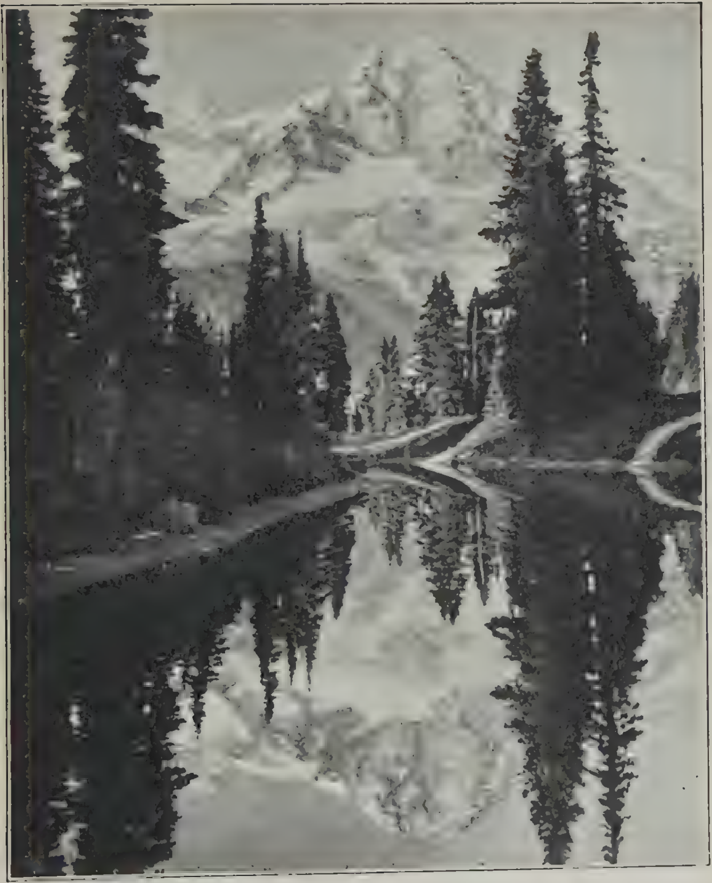


FIG. 324. MT. RAINIER REFLECTED IN MIRROR LAKE, MT. RAINIER NATIONAL PARK, WASHINGTON

Turn the picture upside down to see how the image is reversed in the reflection. Is your image reversed in the same way when you look into an ordinary mirror? (Courtesy of the Union Pacific System)

371. †Light travels in straight lines; shadows. When children play hide and seek, the one who is "it" can often hear the others who are hiding when he cannot see them. This is because sound waves will bend round corners, but light waves will not (Fig. 325). Shadows furnish a familiar means of proving that light travels in straight lines.

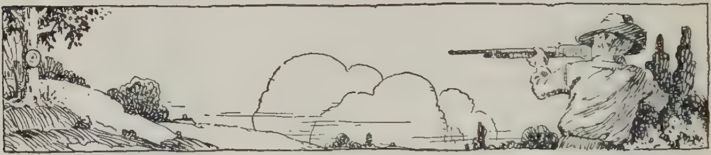


FIG. 325. SHOOTING STRAIGHT AT THE MARK

How does this figure illustrate the fact that light travels in straight lines?

†If you observe a shadow you will note that the middle of it is very dark, and that its edges are less dark. Thus if a bright light is thrown upon a ball held near a wall, the shadow will look like the one in Fig. 326. Try this. The dark part of the shadow is called the *umbra*; and the lighter part is called the *penumbra*. The umbra receives no light directly from any part of the source of light, that is, the lamp, while the penumbra receives light directly from part of the source of light. If you stood with your eye in any part

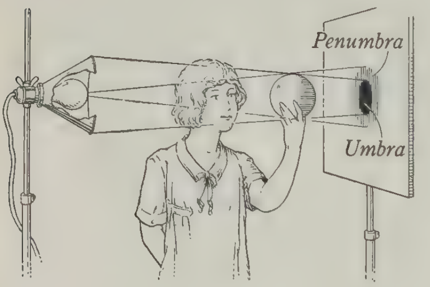


FIG. 326. HOW SHADOWS ARE CAUSED

Is this picture in any way like Fig. 161, *A*, p. 270, which illustrates an eclipse of the sun?

of the umbra and looked directly toward the source of light, you could not see any of it; but if you stood with your eye in any part of the penumbra and looked directly toward the source of light, you could see part of it.

Can you make a correct statement of the following sentences by putting either the word "umbra" or the word "penumbra" in the blanks? Explain.

A total eclipse of the sun can occur only when the moon's ____ reaches the earth.

During the night we are in the earth's ____.

Experiment 80. Does light change its direction as it passes from one transparent substance (water) into another transparent substance (air)? Put some object, such as a pebble or a penny, in a dish or a cup. Stand so that as you look over the edge of the dish you can see about half the pebble. Without changing the position of your eye, pour water into the dish gently so as not to move the pebble. Can you now see all the pebble? half of it? any of it? Make a complete statement answering the question at the beginning of this experiment.

372. *Refraction. Light changes its direction when it passes from one transparent substance into another. If you hold a pair of glasses a foot or so from your eyes and look through them at some object in the room while you turn the glasses this way and that, the object will seem to change its position. When the light from the object passes from the transparent air into the transparent glass, it changes its direction. When it again passes from the glass into the air on its way to your eyes, it changes direction once more. The object seems to change its position because all parts of the glass are not equally thick. The light therefore is bent more wherever it has to travel farther through the glass. This bending of light rays, or changing of the direction of light as it passes from one transparent substance into another, is called *refraction* (Fig. 327).

Experiment 81. Does refraction of light make a fish look nearer to the surface than it really is or farther below it? Stand some object, such as a fountain-pen cap, upright in a glass of water. Let the top of the cap represent a fish swimming in the water. Now look directly down into the glass and, without changing the position of your eye, place your finger against the outside of the tumbler opposite where the top of the cap looks to be. Without moving your finger from the glass, look through the side of the glass to see whether your finger is above or below the top of the cap. Make a complete statement answering the question at the beginning of this experiment.

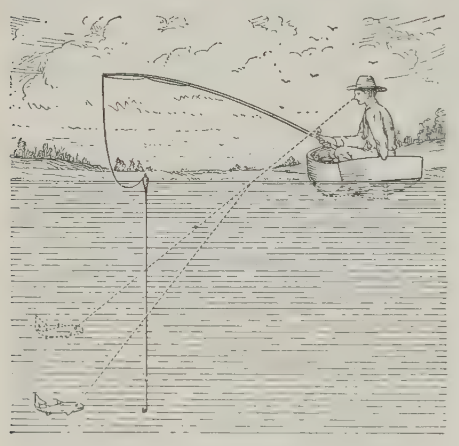


FIG. 327. REFRACTION OF LIGHT

The boy and the fish can see each other because each reflects sunlight. The light from the boy is refracted as it passes from the air into the water. The light from the fish is refracted as it passes from the water into the air. How does the fact that objects often look out of shape when seen through ordinary window glass prove that glass refracts light?

You will remember that the atmosphere becomes denser the nearer it is to the earth's surface. The light from the heavenly bodies, therefore, is refracted; that is, it changes its direction as it passes through the air and is bent into a sharper and sharper curve as it passes through denser atmosphere near the surface of the earth. For this reason we are able to see the sun a little before sunrise and a little after sunset.

Special Reports. How are mirages caused? How are refraction and reflection of light used in a periscope to enable people to see around corners (Fig. 328)?

Project. To construct a simple periscope. The photograph and the diagrams here show a simple periscope which a boy in the eighth grade made out of two right-angled prisms and a hollow tube like those in which maps and calendars are mailed. He also made a still simpler one, using two small mirrors in place of the prisms.

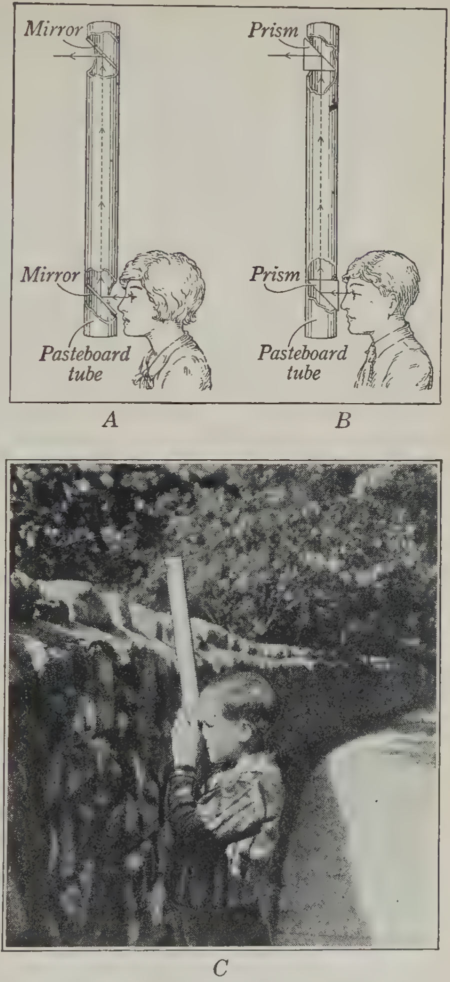


FIG. 328. A HOMEMADE PERISCOPE

The prisms serve as mirrors (*A* and *B*) by reflecting the image of the scene viewed through the periscope

373. *Colors. If you look through a glass prism at any object, the outlines of the object will appear to be beautifully colored. If now you hold the prism in direct sunlight, you will see a beautiful rainbow-colored spot of light where the light has passed through the glass. The explanation is this: Sunlight is known to be made up of all the colors of the rainbow. These colors blend so gradually one into the next that we cannot tell where one color ends and the next color begins. Of the thousands of colors that make up the sunlight we are able to distinguish clearly seven color bands — violet, indigo, blue, green, yellow, orange, and red. When sunlight passes from air into glass the different colors that make up the white sunlight are refracted. The colors are not refracted equally, however. The violet is refracted most, the indigo a little less than the violet, the blue a little less than the indigo, and so on through all the colors to red, which is refracted least (Fig. 329).

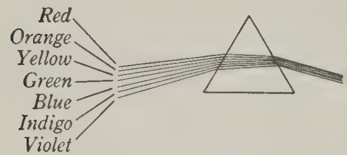


FIG. 329. REFRACTION OF LIGHT THROUGH A PRISM

When light passes through a prism, the colors which compose the light are separated by refraction. Why do we see rainbow colors in diamonds, cut glass, and expensive crystal beads?

*The rainbow is formed whenever the white sunlight is refracted through raindrops in such a way that we see the separate colors. We can never see the rainbow unless our backs are to the sun. The light is then refracted through the drops of water and reflected from the opposite side of the drop to the eye (Fig. 330).

Experiment 82. What is the true shape of the rainbow? Adjust a hose so that it makes a fine spray. Stand in the direct sunlight early in the morning or late in the afternoon, with your back to the sun. Observe the rainbow as you spray the water directly away from the sun. This experiment may be performed after dark by using an automobile headlight as a source of light instead of the sun. Is this rainbow more or less nearly a perfect circle than the rainbow seen in the sky? Can you explain why? Which color is inside in your rainbow? Which color is outside? Perhaps you can see a double rainbow, one inside the other. If so, are the colors arranged in the same order in both?

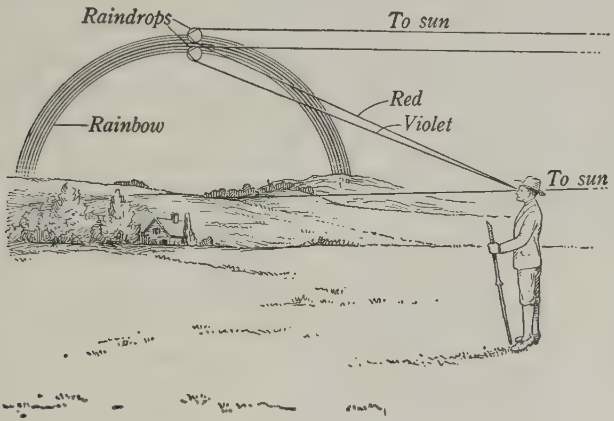


FIG. 330. DIAGRAM SHOWING HOW A RAINBOW IS FORMED

Note how the light is refracted as it passes into and out of the drops, and how the light is reflected from the back of the drops. The paths of only the two outside color beams are here shown. Why do we never see a rainbow at noon?

374. *What causes objects to be colored? The color of this book is red. The reason is that when the sunlight strikes the book, fewer red rays are absorbed than rays of the other colors, although some rays of all the colors are absorbed. The result is that the book appears red because it reflects back to our eyes more red rays than rays of any other color. Similarly, grass and trees are green (Fig. 331) because they absorb fewer green rays than rays of all the other colors; hence more green rays are left to be reflected back to the eye. An object looks white when all the colors of the sunlight are reflected to the eye equally; an object looks black when all the colors composing the sunlight are absorbed. When paints are mixed together, the resulting paint has the color of the rays of sunlight which are least absorbed; this color is therefore most abundantly reflected back to the eye.

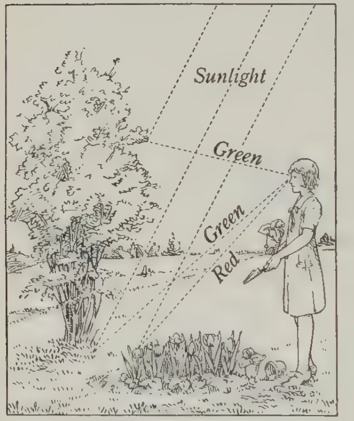


FIG. 331. WHY OBJECTS ARE COLORED

Sunlight is composed of all colors of light. The green tree and the green grass absorb the other colors more than they absorb green. Therefore they reflect more green to the eye. Hence the tree and the grass look green. Can you explain similarly why the tulips look red?

When objects are transparent or translucent, so that part of the light passes through them, they have the color which is least absorbed in passing through. Water is colorless because all the rays pass through in equal amount. The light behind a piece of blue glass is blue because when all the colors entered the glass, fewer blue rays were absorbed by the glass and therefore more blue rays passed through than other rays.

> Green cloth in green light looks green, and red cloth in red light looks red; but red cloth in green light, or green cloth in red light, looks black. Explain.

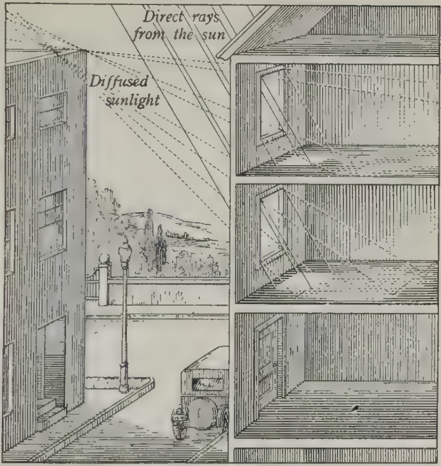

Direct rays from the sun
Diffused sunlight

FIG. 332. HOUSES ARE LIGHTED MOSTLY BY DIFFUSED LIGHT

The direct rays from the sun fall on the bright patches on the floor. The rays of diffused light which come from all directions strike farther into the rooms

375. *The sky; natural sources of light. The sky looks blue to us probably because of the diffusion of the light by the dust particles in the air. The short blue waves are scattered more than are the longer red ones.

*The sun is the earth's main source of natural light, because the other stars are too far away to furnish us much light (see page 253). The moon is the only other important natural source of light. It has no light of its own, but it reflects to us some of the light which reaches it from the sun (see page 268).

Can you think of other sources of natural light?

Can you draw a diagram showing how the sun's light is reflected to us at night from the moon?

376. †Sunlight in the home. Out of doors in the bright sunshine the light is about ten times as bright as it is in the shade; out of doors in the shade the light is brighter than it is *near* the windows inside a well-lighted house; away from the windows the light in many houses is too dim for reading or for many other purposes. Why is this true?

†The daylight comes slanting through the windows into our homes. Most of our rooms get little direct sunlight. They are lighted largely by diffused sunlight (see page 598), which is reflected mostly from clouds and dust particles in the air. All the direct sunlight passes through the window at the same angle, but the diffused sunlight enters at many angles (Fig. 332).

> Why should windows extend as nearly to the top of the room as possible?

†Houses are usually provided with from one fifth to half as much window area as floor area. A house built close to other houses or in a grove of trees needs more window space than a house by itself in the open. Moreover, windows frequently fail to admit sufficient light because of heavy curtains and shades. Window shades in living rooms are needed chiefly to shut out the direct sunlight when it is unpleasantly bright and dazzling. Light-colored translucent shades are better than dark-colored opaque ones. Why?

> Many people like to pull the shades part way down. Why does this practice shut out considerably more than half the useful light from the room?

†The amount of natural light that brightens the inside of our houses does not depend entirely upon the amount of window space or upon the kind of shades and the way in which we use them. The color of the walls and ceilings and of the woodwork and furniture has much to do with the amount of light in a room.

†Much of the light we use is reflected one or more times from the floor, walls, ceilings, or furniture before it reaches the place where we use it. Light colors absorb less light than dark colors (Fig. 333). If we want to dif-

fuse as much light as possible throughout the rooms, therefore, we should use light colors for our walls and ceilings. A room in which the floors, the hangings, the furniture, and the walls and ceilings are all dark is sure to be dim and gloomy. Light oak-wood finish reflects more than twice as much light as dark oak finish and about four times as much as walnut or mahogany finish. A wall or ceiling of very light gray reflects about four times as much light as one of dark gray, and light pink reflects about four times as much light as dark red. Dark shades of almost any commonly used color frequently absorb as much as four fifths of all the light that strikes them, leaving only one fifth to be diffused about the room. The delicate light shades of yellow and red are not only good reflectors of light but also give a cozy and cheerful appearance to the room. Glossy finishes reflect more light than dull finishes, but the reflection from the glossy surfaces is apt to be glaring and to strain the eyes.

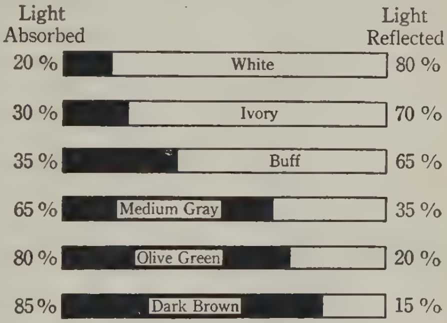


FIG. 333. LIGHT COLORS MAKE BRIGHT HOMES

About how many times as light would a room be if its walls and ceilings were painted white than if they were painted dark brown? About how many times as much light would a medium gray floor reflect than if it were painted dark brown?

377. *Artificial light. It is possible to work and to play at night by means of artificial light. Fires were man's first source of artificial light. At first he had to remain beside the fire which gave him light, but finally he learned to carry a blazing branch or knot away from the fire. Thus the torch was the first lamp.

378. *Oil lamps. Thousands of years passed before man learned to make crude stone lamps. At first these lamps were merely flat hollow stones. Oil was put into the hollow, and a crude wick of rush or twisted flax or cotton was stuck into the oil and lighted. Later man made these lamps out of pottery and, still later, out of bronze and other metals. The first oil lamp with a chimney was invented only a little over two hundred years ago. Kerosene-oil lamps came into use about seventy years ago and are still in wide use where electricity is not easily obtainable.

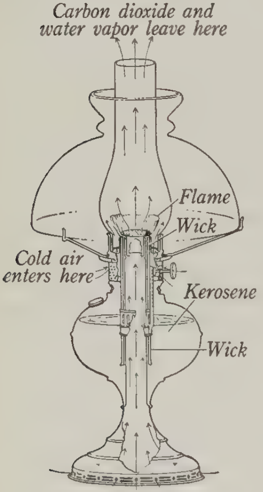


FIG. 334. DIAGRAM OF A KEROSENE LAMP

In what ways is the burning lamp like a stove (Fig. 115, p. 190)?

We have learned that the common fuels contain compounds of carbon and hydrogen (see page 204). When the oil at the top of the wick in oil lamps is heated to the kindling temperature, the oxygen in the air combines with the carbon and the hydrogen in the oil to form water and carbon dioxide. The water is, of course, in the form of a vapor. But not all the carbon is oxidized, and the incandescent solid particles of carbon in the flame give off the light.

*In the kerosene lamp (Fig. 334) the oil rises through the porous cloth wick by capillarity (see page 354).

When the wick is lighted, the oil at the top of the wick burns, setting up convection currents (see page 166).

Can you explain the action of the lamp by choosing the correct term from each pair in the following paragraph?

When the wick is lighted, the air above the wick becomes cooler warmer. It therefore expands contracts, making the air pressure inside the chimney greater less than the air pressure outside the chimney. More air is therefore sucked in pushed in through the air holes by the partial vacuum inside the greater air pressure outside. Fresh supplies of oxygen are thus supplied to the flame.

When the wick is turned too high the lamp smokes. Why? If something were placed over the top of the chimney or if the air holes were stopped up, the lamp would smoke and the flame would soon be extinguished. Explain.

*The wicks of kerosene lamps should be soft, well-fitted, and long enough to trail about two inches on the bottom of the oil reservoir. As soon as these extra two inches have been burned and trimmed away, the wick should be replaced. The lamp should be filled each day so as to prevent too large a space above the oil in the reservoir. There is danger in lifting and carrying a lighted oil lamp or in extinguishing it by blowing *down* the chimney, for if the flame should be forced into the oil vapor an explosion might result. It is safer to blow *across* the chimney. If sediment is allowed to collect in the oil reservoir, it will stop up the capillaries of the wick so that it will not be able to supply sufficient oil to the lamp.

379. †Candles. Candles were known about four thousand years ago, but were too expensive for general use until the fifteenth century. They were an important source of light in the early history of this country until the kerosene lamp became popular. They still find a use on dining tables, where they furnish a soft, pleasing light; but they are apt to interfere with the view across the table and, if unshaded, to strain the eyes.

380. Gas lamps. Natural gas began to be used as a fuel and for lighting early in the last century; later heating gas was made from soft coal. Where electricity is not yet available we find these two kinds of gas still being burned for light. The early gas lights were merely gas pipes. The gas was lighted as it escaped from the end of the pipe. Later the open ends were equipped with various devices to spread the flame (Fig. 335). The oxygen in the air combined with the carbon and hydrogen compounds in the gas to produce water and carbon dioxide, as always happens when any fuel burns (see page 204). Some of the

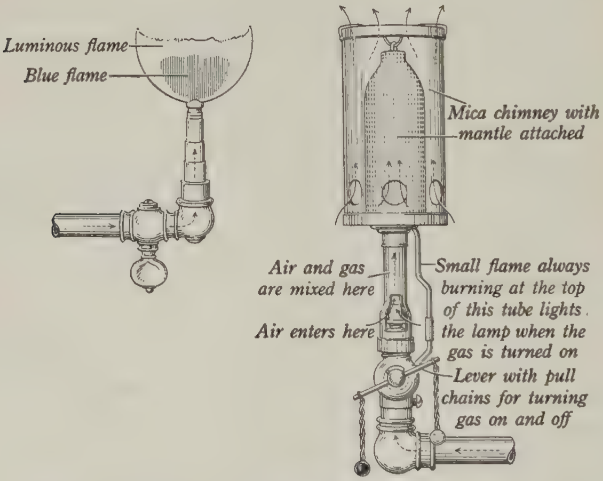

Luminous flame
Blue flame
Mica chimney with mantle attached
Air and gas are mixed here
Air enters here
Small flame always burning at the top of this tube lights the lamp when the gas is turned on
Lever with pull chains for turning gas on and off

FIG. 335. EARLY AND MODERN TYPES OF GAS LAMPS

carbon, however, was not oxidized. Incandescent solid particles of unburned carbon caused most of the light.

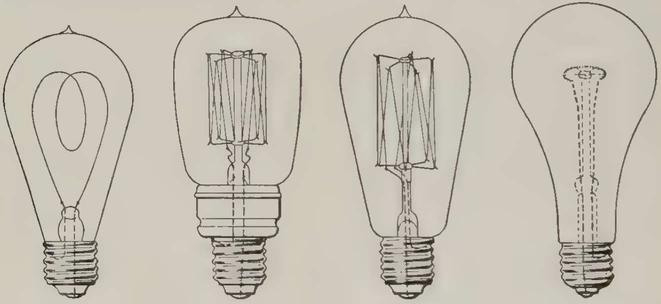
Years ago, in hotels where this type of gas flame was used, the sign "Do not blow out the gas" was put up in the bedrooms. Explain (see page 204).

*Later the gas lamp was greatly improved by the invention of a mantle. This thimble-shaped mantle is woven out of cotton or artificial silk and is saturated with solutions of thorium and cerium, two rare metals. A burner much like that of the gas stove is fitted over the gas pipe. The mantle is hung over this burner (Fig. 335). The amount of air allowed to enter with the gas is controlled so that the carbon is all oxidized. The intense heat from the blue flame heats the mantle to incandescence, giving a much brighter and more nearly white light than was possible with the open-flame type.

Special Report. How is an arc light constructed? For what purposes is it still used?

381. The incandescent lamp. Many scientists contributed to the invention of the incandescent electric lamp, but it was the experimenting of J. W. Swan and Thomas Edison that resulted in the first successful carbon-filament lamps, about fifty years ago. In the early incandescent lamps a carbon filament in a vacuum globe (Fig. 336, *A*) was heated to incandescence by the passage of an electric current through it. The carbon-filament lamp is used very little now.

*Several electric lamps have been invented in which a metal filament is used in place of the carbon (Fig. 336, *B*, *C*, *D*). Tungsten-filament lamps are now used almost entirely, because they can be operated at much higher temperatures than carbon and last even longer. The filament of the earlier tungsten lamps was placed in a vacuum globe, like that of the carbon lamps, but recently gas-filled bulbs have rapidly been replacing the vacuum globes. The first gas-filled tungsten lamps were filled with nitrogen. Nitrogen-filled lamps are no longer manufactured, because argon, a heavier, inactive gas, has been found to be superior to nitrogen for this purpose. It is probable that practical means will be found to make gas-filled lamps using other inactive gases which will prove even more satisfactory than argon (see page 40).



A. Carbon *B. Tantalum* *C. Vacuum tungsten* *D. Gas-filled tungsten*

FIG. 336. EARLY AND MODERN TYPES OF ELECTRIC LAMPS

You cannot afford to burn lamps like *A* and *B* because they use too much electricity for the light they give; *C* is fast going out of date, its place being taken by *D*. This new lamp gives more light for the electricity used; it reduces glare because it is frosted; it is easily kept clean because it is frosted on the inside

*The gas-filled lamps give a better quality of light than the vacuum tungsten lamps and use less electrical energy; in other words, gas-filled lamps are more efficient than vacuum lamps, especially in the larger sizes. The small vacuum tungsten lamp is still widely used, because suitable methods of making small gas-filled lamps, that is, those of twenty-five watts or less, have not yet been found.

Before 1923 all the electric signs in this country were made up of separate electric lamps of various colors. Our attention is now attracted by beautiful orange-red, blue, and green signs in which often a whole word is made up of only one lamp. These lamps are glass tubes made in any length and bent into any desired shape. All the air is first exhausted from the tube, then neon, argon, or helium (rare gases which exist in the air) and sometimes a little mercury are admitted to the tube. The tube is then sealed in a flame. The pressure of this gas within the tube is very low. The electric current, which passes through this gas between terminals sealed into the ends of the tube, produces

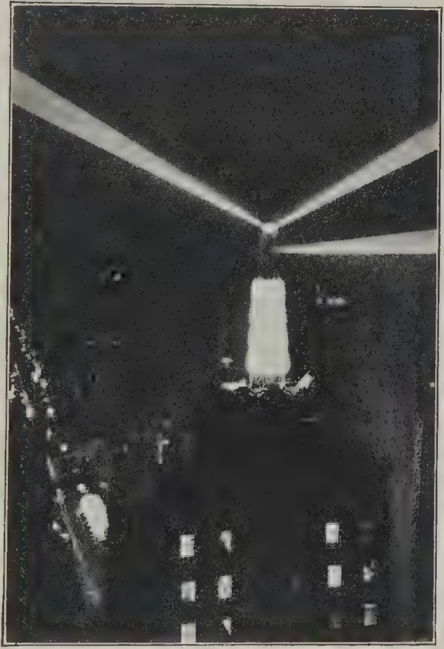
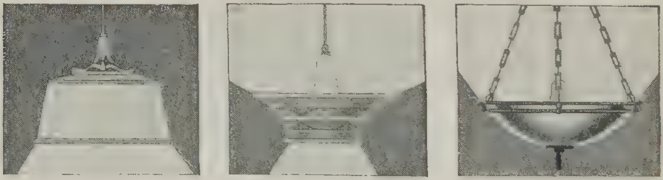


FIG. 337. THE CLAUD-NEON AIRPLANE BEACON ON THE TOP OF THE ROANOKE BUILDING, CHICAGO

This beacon is five hundred and twenty feet above the street. Above the orange-red tube lamps, which are white in this picture, is an eight-thousand-candle-power revolving searchlight. The neon light can be seen better in fog than other types of light the illumination. Neon gas gives orange-red light; mercury vapor produces green or blue light. Other colors are produced by putting more than one of these gases into the tube and by using a special kind of glass. The orange-red neon lights are claimed to be the only lights visible through fog; therefore they are being used not only for electric signs but also for lighthouse and airplane beacons and for marking airplane routes (Fig. 337).

> ***Special Reports.*** How are gasoline lamps constructed? In what respects are they better or poorer than kerosene lamps?

382. †Artificial lighting requires careful planning. The same conditions which make a house bright and cheerful by daylight will make it bright and cheerful at night. It is just as important that we should have light-colored walls and ceilings for artificial lighting of our rooms as for natural lighting. It is important that our lamps be so chosen and arranged as to have the illumination bright enough in all portions of the room for whatever we want to do, and so as to have at the same time the least possible strain on the eyes. There is no real saving in using too small lamps or too few. Too bright lamps, producing a glare, are likewise to be avoided.



A. Direct lighting *B. Semi-indirect lighting* *C. Totally indirect lighting*

FIG. 338. THREE COMMON TYPES OF HOME LIGHTING

†There are two reasons why no lamp should burn without a shade: (1) an unshaded lamp gives a dazzling spot of light, thereby causing too great a contrast with the dim portions of the room, and (2) it causes much eyestrain whenever one looks at it.

383. *Types of illumination. There are three common ways of lighting a room with electric lamps: by direct illumination, by semi-indirect illumination, or by totally indirect illumination. In direct lighting (Fig. 338, *A*) most of the light is reflected downward. An ordinary lamp or a desk lamp is a good example of direct lighting.

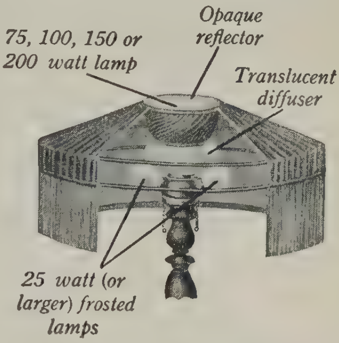

Opaque reflector
75, 100, 150 or 200 watt lamp
Translucent diffuser
25 watt (or larger) frosted lamps

FIG. 339. AN EXCELLENT TYPE OF FLOOR LAMP

Will this lamp serve best with light or with dark walls?

*In semi-indirect lighting (Fig. 338, *B*) the lamps are placed in a bowl with a translucent bottom. Some of the light passes through the bottom, but most of it passes directly to the ceiling or is reflected there by the opaque reflector. It is diffused by the ceiling throughout the room (see page 598).

*In totally indirect lighting (Fig. 338, *C*) the lamps are placed in an opaque bowl which reflects the light to the ceiling. The ceiling diffuses the light about the room.

†An excellent type of floor lamp is shown in Fig. 339. The lamp has two separate lighting units, one direct and the other semi-indirect. The two small lamps furnish direct light for reading, and the larger lamp, in an opaque reflector, lights the whole room by diffusion from the

ceiling. At the same time the larger lamp diffuses enough light through the translucent bowl to light the floor below without the aid of the small lamps.

*More of the light is lost by semi-indirect and totally indirect lighting than by direct lighting. But semi-indirect lighting and totally indirect lighting give a better quality of light because of the diffusion, and they give a more even illumination and less shadow. Dust forms a dark coating on the walls and the ceilings and on the lamps and shades. This coating of dust may absorb more than half of all the light. Therefore it is necessary that lamps and shades, as well as walls and ceilings, should frequently be cleaned.

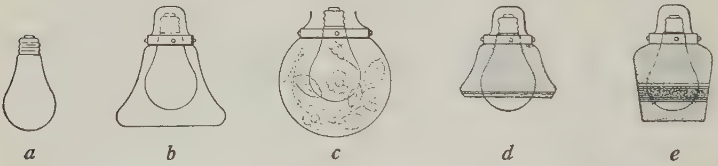


FIG. 339 A. FOUR POOR TYPES AND ONE EXCELLENT TYPE OF LAMP FIXTURE

*Fig. 339A illustrates five types of lighting fixtures commonly found in homes. Of these, only *e* illustrates good practice. The unshaded lamp (*a*), the lamps in transparent glass shades (*b* and *c*), and the lamp which extends below the translucent or opaque shade (*d*) should all be avoided for the two reasons which are given at the top of page 617. Every lamp ought to be provided with a translucent or an opaque shade somewhat longer than the lamp, as in *e*.

Special Reports. Make a careful study of the lighting in your school building. What changes can you suggest for improving it? Make a similar study of the lighting in your home.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. Rough glass a windowpane a smooth pond the ocean smooth unpolished iron makes a good mirror.
2. When light passes from air into water it is very largely refracted absorbed reflected diffused destroyed.
3. Trees and houses often appear bent and twisted when they are looked at through ordinary window glass because of ---- of the light.
4. Sunlight is made up of many colors of light.
5. When we see a rainbow the sunlight is both ---- and ---- as it passes through the raindrops.
6. A lemon looks yellow because it absorbs more rays of yellow light than rays of other colors.
7. In a kerosene or gasoline lamp, chemical energy is transformed into ---- energy and ---- energy.
8. The most efficient electric lamp is one that contains a carbon filament in a partial vacuum a tungsten filament in argon a tungsten filament in nitrogen a tungsten filament in air a tungsten filament in a partial vacuum.
9. A book placed just below a reading lamp furnishes an example of indirect illumination.
10. Light reflected from the ceiling is an example of direct illumination.

CHAPTER XXXIV

THE EYE, AND INSTRUMENTS TO HELP THE SIGHT

Some Questions this Chapter Answers

What are lenses? What are the parts of the human eye? In what ways is the eye like a camera? How do we see? What facts should one know about the care of the eyes? How do telescopes, microscopes, and opera glasses help us to see? How are photographs made? Why do moving pictures seem to move? Why is the spectroscope important in scientific work?

384. Learning to use refraction. Thousands of years ago primitive man knew that in order to spear a fish he must aim below the spot where the fish looked to be in the water (Fig. 327, p. 602). Thus he took refraction into account without knowing anything about refraction itself. During perhaps the last three thousand years men have begun to learn to make instruments that enable them to *use* refraction in many useful and pleasant ways.

*When we studied refraction we learned that whenever light passes from air into glass, it changes its direction, or bends. The thicker the glass, the more the bending. Pieces of glass called lenses, shaped like those in Fig. 340, are made so as to refract light in certain ways.

Experiment 83. Do objects look larger or smaller through convex and concave lenses? Hold a convex lens and a concave lens in turn near some object, such as the back of the hand or a page of printing. Fill the blanks in the following sentence with the word "convex" or the word "concave":

> A ____ lens magnifies objects (that is, makes them look larger than they really are); a ____ lens makes objects look smaller than they really are.

Experiment 84. Can fuel be ignited by refracting sunlight upon it through a lens? Hold a convex lens in direct sunlight. Move a piece of paper back and forth behind the lens until the paper is exactly at the point where the sunlight passing through the lens is brightest. This spot is called the *focus* of the lens. What do you observe? Place a piece of wood exactly at the focus. What happens?

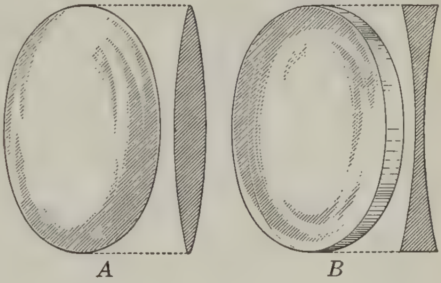


FIG. 340. CONVEX AND CONCAVE LENSES

Each lens is shown as it looks when partly turned toward you and when seen from the side

An ancient convex lens (Fig. 340, *A*) which had been carved out of rock crystal at least as early as 600 B.C. was recently found in the ruins of an Assyrian palace on the banks of the river Tigris. It is probable that these ancient Assyrians knew that convex lenses could be used to magnify objects and to light fires. Not much more was learned about lenses until centuries later. All the important optical[1] instruments, moreover, in which lenses are used (for example, the telescope and the microscope) were invented less than a thousand years ago.

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[1] *Optical* (op'ti kl): relating to vision; having to do with seeing.

385. †The human eye. During the eleventh century an Arabian scientist, Alhazen, made a study of the parts of the eye. He explained how the convex lens in the eye (Fig. 341, *A*) enables us to see. His writings are thought to have led to the invention of spectacles about two hundred years later by the English scientist Roger Bacon.

Experiment 85. What is the inside of an eye like? Secure from your butcher two or three fresh eyes from cows or pigs. With sharp-pointed scissors cut off the lids so that you have only the eyeball. Note the optic nerve at the back. Insert the point of the scissors into the back of the eyeball just above the optic nerve. Is the outer coat of the eye easily pierced? Is there any advantage in having the outside coat of the eye like this? Cut out the optic nerve so as to leave a small opening in the back of the eyeball. Try to keep the jelly-like liquid inside the eyeball from escaping. Now hold the eyeball so that you can look toward the front of the eye through the opening you have cut. By moving your head slightly you will be able to see through the eye the image of objects in front of the eyeball. This image you see is the same sort of image which the cow or the pig saw with the eye. Is it right side

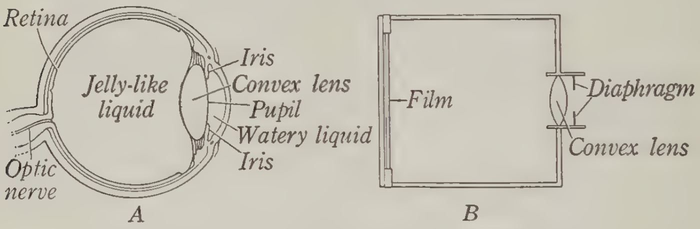

FIG. 341. THE EYE IS LIKE A CAMERA

Which of the essential parts of the eye correspond with essential parts of the camera?

up or is it upside down? Make the opening in the back of the eyeball larger and allow some of the liquid to escape. Is it transparent? Examine the inside coating at the back of the eye. This is the retina. Carefully remove the jelly-like liquid until you discover the lens. What is its shape? Examine the front of this lens for the iris, which you will find as a dark-colored coating over part of the lens, but with a round opening in the middle. This round opening is the pupil. In front of the iris is a watery liquid.

386. *The eye like a camera. The iris of the eye is a diaphragm (Fig. 341, *A*, *B*). The iris controls the amount of light that enters the eye just as the diaphragm controls the amount of light that enters the camera. When the light is very bright the iris closes up so as to make the pupil (the window into the eye) smaller; when the light is dim it opens up so as to allow more light to pass through the pupil. You can see how the iris opens and closes as the light becomes dimmer or brighter thus: Have a member of your class cover his eye with his hand so that his open eye is in darkness for a minute or so. Watch the iris of his eye as he takes his hand away. Does the pupil get larger when the bright light strikes the eye or smaller?

Why do people close their eyelids in bright light? Why do your eyes hurt when you come into a bright light from the darkness? How does the iris of a cat's eye differ from the iris in your eye?

Special Report. Examine a camera and find out the purpose of each part.

Experiment 86. How do convex lenses make images? Hold a convex lens, such as a reading glass, in the window. Move a sheet of white paper back and forth behind the lens until you see on the paper an image of the scene outside the window. Is the image right side up or upside down?

387. †Refraction in the eye. When the light from the top of the object passes through the lens, it is refracted so that it passes out through the bottom of the lens (Fig. 342, *a*). Similarly, the light from the bottom of the object is refracted so that it passes out through the top of the lens. Thus the image is upside down, or inverted. Thick lenses refract the light more than thin ones, because the light has to pass through more glass. Thus the image is closer to the thick lens than to the thin one (Fig. 343, *a*, *b*).

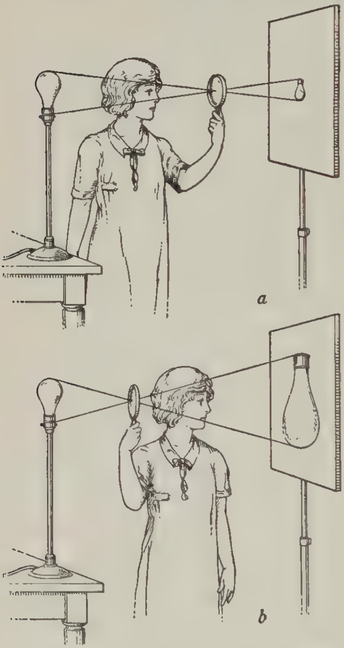

FIG. 342. HOW IMAGES ARE FORMED WITH A CONVEX LENS

The image is closer to the lens when the object is farther from the lens than when the object is closer to the lens

*In Fig. 343, *a*, *b*, we see that thick lenses have their images closer to the lens than thin lenses do. In Fig. 342 we saw that the image was closer to the lens when the lamp was farther away. The retina, which receives the images in the eye, cannot move forward and backward as we moved the screen in Fig. 343, *a*, *b*: it must stay the same distance from the lens. The lens in the eye, however, is so constructed that it can become thinner when objects are far away and thicker when objects are near. Thus it is able to keep the image refracted on the retina (Fig. 343, *c*, *d*).

388. †Care of the eyes. When the eye is looking at a distant object or when we are asleep, the eye muscles are relaxed[1] and the lens is as thin as it can get. When we look at close objects, the muscles contract in order to make the lens thicker. If we look at objects near the eyes for a long time, the eye muscles become tired and our eyes feel strained. When one reads for a long time, then, it is

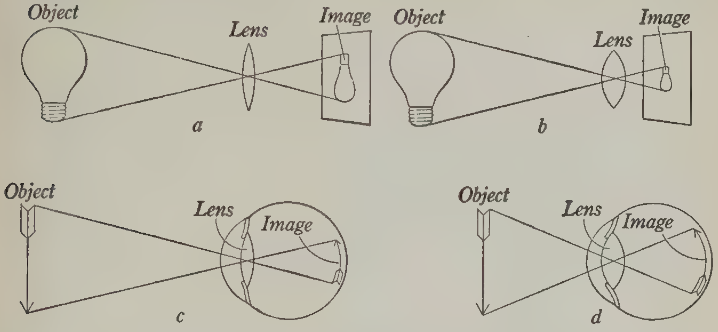

FIG. 343. HOW IMAGES ARE FORMED IN THE EYE

The lens of the eye must become thicker in order to enable us to see near objects and thinner to enable us to see distant objects

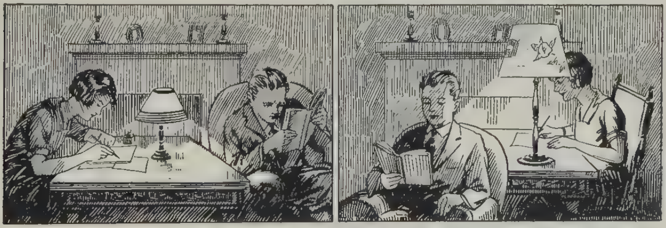

FIG. 344. CARE OF THE EYES

In what ways does one picture illustrate bad practice and the other good practice in reading and writing by lamplight?

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[1] *Relax* (re lax′): to loosen; to relieve from strain.

better to relax the eye muscles frequently by closing the eyes for a moment or by glancing at some distant object. Many people injure their eyes by reading in too bright or too dim a light (Fig. 344). One should never read in bright sunshine (Fig. 345) or in twilight.

Special Reports. What is meant by nearsightedness? by farsightedness? Show by diagrams how nearsightedness is corrected by means of concave glasses and how farsightedness is corrected by means of convex glasses. Describe what is meant by "astigmatism." What is color-blindness? Color-blind men are not allowed to become railroad engineers. Why?

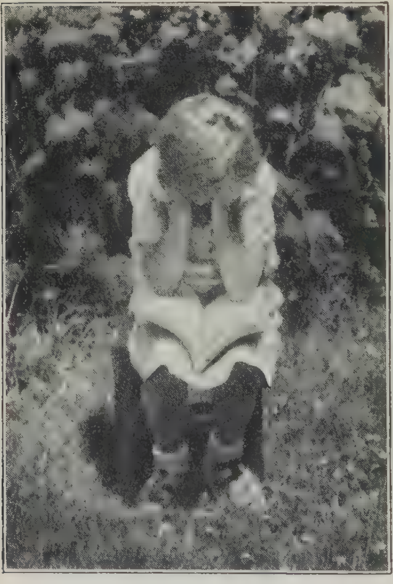

FIG. 345. INJURING THE EYES

In what two ways is this girl injuring her eyes? Note the shadow to find out where the sun is

†If you find that your eyes pain you or that you do not see clearly, it is very important that you should at once consult the best eye specialist you can find and not wait until eye trouble develops. Sometimes you can prevent serious eye troubles which might develop when you are older. Children often need glasses before their eyes give them such trouble that they know they need to consult a physician. In all cases it is best not to consult a doctor who advertises. Sometimes foolish and

vain people will not wear glasses at all, or will not wear them all the time that the physician advises. Such persons are running the risk of injuring their sight permanently.

†Do not buy patent medicines for the eyes. Several different kinds of drops and salves which claim to cure diseases of the eye can be bought at drug stores. These remedies are labeled with deceiving statements such as "Throw away your glasses," "A reliable relief for sore, red, inflamed, and itching lids," "Eye tonic," and the like. Patent medicines do harm in at least two ways: (1) they do not cure or relieve the diseases which their labels claim to relieve and (2) they too frequently cause people who try them to put off consulting a doctor until it is too late to be cured.

FIG. 346. A HOMEMADE TELESCOPE

The first practical telescope is said to have been invented in Holland about 1608. This was not like a modern telescope but was similar to an opera glass

389. †Optical instruments. Many of the great discoveries of modern science are made with the use of optical instruments. Among the most important of these instruments are the microscope and the telescope. The microscope is used to study objects too small to be seen with the naked eye (Fig. 2, *b*, p. 7); the telescope is used to study huge objects, such as the stars and planets, which are too far away to be seen clearly with the naked eye. A simple microscope is a convex lens (a reading glass, for example) held close to the object. A compound microscope has two thick convex lenses so arranged that the second lens magnifies the image which the first one makes. A telescope contains two lenses, one thin and the other thick. The thin lens, in the front of the telescope, gives an image of a star; the thick lens, in the other end, gives a magnified image of the first image.

> *Project.* To make a simple telescope. Fig. 346 shows a telescope made by a girl in the seventh grade. You can make one like it very easily. Place a thin convex lens in a lens holder near the end of a meter stick. Place a thick convex lens in another lens holder near the other end of the stick. Aim the "telescope" out of the window at some distant object, such as a house or a tree (Fig. 346). As you move the thick lens slowly toward the thin lens keep your eye close to it until you see the object clearly through both lenses. Turn the telescope end for end so that you look through the thin lens toward the thick one. Can you see the distant object through the lenses now? Is the image in the telescope right side up or inverted?

†Opera glasses are more convenient than telescopes for many uses, because they give images right side up and because they are small and easily carried. The opera glass has a convex lens in front and a concave lens in the end through which the eye looks.

390. *Making images permanent. Photographs are produced by transforming light energy into chemical energy. When the lens refracts the image upon the plate of the camera (Fig. 341, *B*, p. 622), the light energy acts upon the compounds of silver on the film in such a way as to leave the image on the film. You cannot see the image on the film until the film is developed. When the film is developed later, the image is made permanent by the action of other chemicals. The film is then a negative. When the negative is placed over special paper, and light is allowed to pass through the negative to the paper, the light produces chemical changes on the paper which print the image of the negative on the paper. When the print is developed we have the finished photograph, or positive. The photographs in this book are reproductions of positives.

Thirty years ago very few people had even heard of a moving picture. Nobody who saw the earliest moving picture "shows" would have dreamed that in so short a time people would be taking their own moving pictures and showing them in their homes.

†Moving pictures do not really move at all. They only seem to move. The reason is this: The moving-picture camera is so built that it can take about sixteen pictures a second on a long celluloid film. Of course the scene that is being photographed cannot change much in one sixteenth of a second; consequently each picture is only slightly different from the one ahead of it. When the film is thrown on the screen at the rate of sixteen pictures per second, the image of one picture does not have time to fade from the retina of the eye before the image of the next picture strikes the retina; therefore the successive images blend into each other so that we are not conscious that we are seeing separate pictures.

Special Reports. How are motion pictures made? How are slow-motion pictures made?

391. The spectroscope. The spectroscope is an instrument of the greatest importance in science. It makes use of the fact that a prism will separate light into the different colors which compose it. Whenever an incandescent solid or liquid body is looked at through the spectroscope, all the colors of the rainbow are seen in one continuous band, with violet at one end and red at the other and with all the other colors in their proper order between. Whenever an incandescent gas or vapor is looked at through the spectroscope, however, one or more color lines are seen instead of a complete band of colors. These lines are always exactly the same and are always in exactly the same position for any given substance. Furthermore, no two substances ever have the same color lines. Therefore, chemists and physicists make a substance into an incandescent gas; then, by observing it through the spectroscope, they are able to tell what the substance is composed of by noting the color and position of the various lines which they see.

If between the spectroscope and the source of light there is a gas or vapor, the spectroscope shows dark lines in the same places in which bright lines are seen when this gas or vapor is made incandescent and observed through the spectroscope. Hence astronomers look through their spectroscopes at the sun and the other stars and, by noting the number and positions of the black lines, are able to learn many of the chemical substances which compose the stars. In this way they have learned that nearly sixty of the elements (mostly metals) that are found on the earth exist also in the sun; in fact, the gas helium was discovered in the sun's atmosphere by means of the spectroscope long before it was known to exist on the earth. The astronomers have not yet discovered gold, platinum, or mercury in the sun's spectrum; nevertheless these heavier elements may exist there, but so far inside the sun that light from them does not reach its surface where they can be detected with the spectroscope. By means of the spectroscope astronomers are also able to determine whether certain stars are moving toward the earth or away from it and how fast they are traveling.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. Lenses are designed to make practical use of the reflection of light.
2. The image thrown upon the retina of the eye or upon the plate in the camera has its top side up and its bottom side down.
3. In passing through a concave lens the light is bent more at the middle of the lens than at the edges.
4. The lens of a camera is made thicker or thinner in order to secure clear images of near and distant objects.
5. Photographs transform light energy into **electrical energy** **chemical energy** **mechanical energy** **heat** **sound.**
6. In the photograph the light energy acts upon compounds of **iron** **aluminum** **silver** **lead** **tin** ----.
7. In each blank under "Camera" write the name of a part of the camera, and in the blank opposite it under "Eye" write the corresponding feature of the eye:

CAMERA	EYE
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UNIT XV. TRANSPORTATION

CHAPTER XXXV

MOVING PEOPLE AND GOODS ABOUT THE EARTH

Some Questions this Chapter Answers

What has modern science to do with transportation? How does the steam engine operate? How is it possible for steel ships to float? Why is stability important in transportation? How does the gas engine operate? What are some electrical devices which an automobile carries? How does an electric motor operate? How are airplanes and dirigibles able to travel through the air?

392. Modern transportation dependent on science. Have you ever stopped to think of the meaning of the word "homemade"? Can you name half a dozen things which you know were made — every part of them — entirely in your home? How many things can you see about you now which were made entirely in your town? It is hard to think of anything which was not brought here from somewhere else. But if it were not for transportation, everything would have to be homemade.

Two hundred years ago travel and transportation of goods from one part of this country to another was difficult. People traveled and carried their goods by stage-

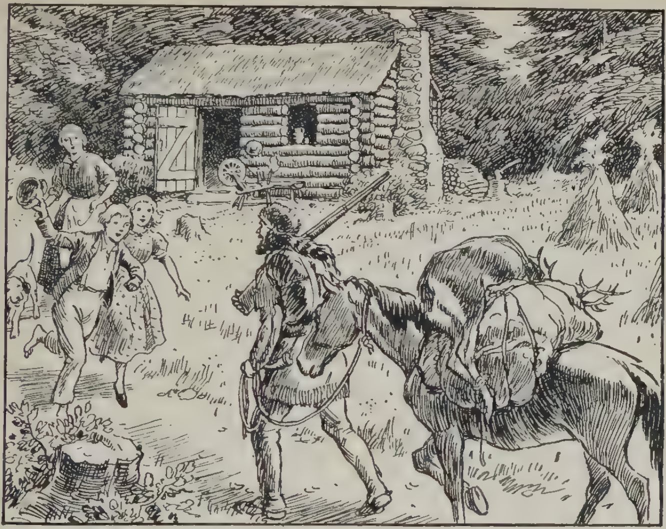

FIG. 347. TRANSPORTATION IN PIONEER DAYS

What fun it would be if you could take these children into your home! How wonderful many things common enough to you would be to them!

"These? Oh, these are sardines. They came from Norway in cans. (You would have to show them the cans before they would know what you meant.) This silk dress? The silk came from Japan, but the dress was made in Chicago. I've been there. It's only about five hundred miles from here. Five hundred miles? Why, that isn't far. What? You've never been ten miles away from home in all your life! Yes, almost everything we have came from far away somewhere. Why we couldn't *live* if we could have only the things we could get here! Do you have to find, or make, or raise almost everything you have, for yourself, or go without? I don't see how you get along at all!"

"How did these things get here? Why, by steamer, by train, by automobile truck, by airplane — What's that? You don't know what I'm talking about? Haven't you ever seen — Oh, no, of course you haven't. No, I think none of these things were brought here on horseback. Did my father carry these things here on his back? Why, no, of course not —."

coach and wagon where the roads were good enough to permit of this, by horseback where there were sufficiently good trails, and on foot where there were not even good trails. Travel and commerce by water were carried on by sailboat, rowboat, or canoe. Travel and transportation by steamboat, railroad train, automobile, or airplane were then unknown.

Progress in transportation, however, like progress in everything else, depends upon progress in science (Fig. 6, p. 17, Figs. 348 and 349). After many centuries of patient experimenting on the part of thousands of scientists, practical steam engines, gasoline engines, and electric motors were brought to their present stage of efficiency. These three great inventions make modern transportation possible. They drive great ships, locomotives which are able to pull a hundred or more cars, automobiles and trucks, airplanes and dirigibles, and electric locomotives and cars.

In this progressive age every boy and girl wants to know something about what makes locomotives, steamships, automobiles, airships, and electric cars go. Most of this information is found in later courses in science. You can learn in this chapter, however, many scientific facts which nobody in the world, not even the greatest scientists, knew fifty years ago.

393. Locomotives and ships. The steam engine drives locomotives and ships. The steam engine, like most other inventions, is the product of several men of genius, but three especially, — Newcomen, Watt, and Stephenson. Thomas Newcomen (1663–1729), an English blacksmith, was one of the first men to see that machinery could be driven by steam power. He took the few things that had been discovered about steam power before his time and, with the help of his assistant, John Cawley, and Thomas

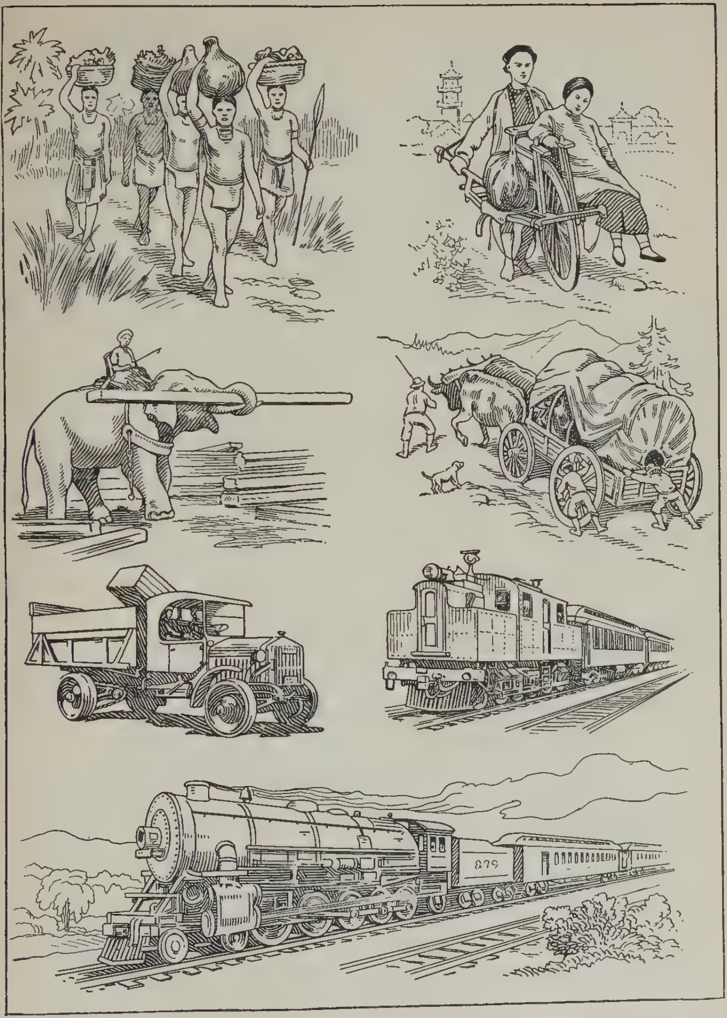

FIG. 348. FROM PRIMITIVE TO MODERN TRANSPORTATION ON LAND

Savery, a military engineer, constructed what is now known as the "atmospheric steam engine." This engine was used to pump water from the deep mines in England.

*James Watt (1736–1819), a Scottish engineer, was an instrument-maker at the University of Glasgow when a model of Newcomen's engine was one day brought to him for repair. He worked for two years trying to improve it. Finally he invented the modern condensing steam engine. The first important use of Watt's engine was lifting coal from the mines and hauling it by stationary[1] engines from the mines to the shipping point.

*George Stephenson (1781–1848) was an English engineer who had worked in the mines from boyhood. He was so interested in the inventions of Watt and other men that he learned to read when he was eighteen years old in order to find out more about them. The problem of transportation interested him so much that he made over Watt's invention into a "traveling engine," the "great grandfather" of our modern locomotive. He himself lived to see many railways in operation as the direct result of these inventions.

What scientific attitudes are here illustrated by the work of Watt and Stephenson?

*The steam engine transforms heat energy into mechanical energy. When water is changed to steam, it expands so much that it takes up about sixteen hundred times as much space as it did before. Thus a cubic inch of water will make nearly a cubic foot of steam. The energy of the expanding steam can be made to do work.

*In the steam engine the expanding steam is made to push the piston back and forth (Fig. 350). The steam

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[1] *Stationary* (sta'shun a ry): fixed in one spot.

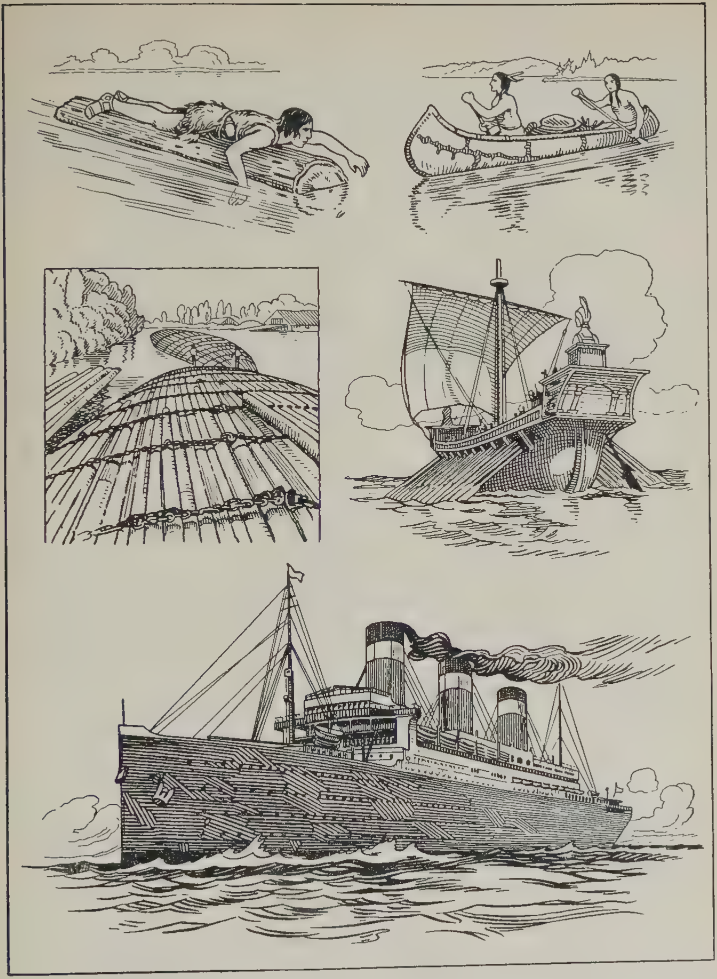

FIG. 349. FROM PRIMITIVE TO MODERN TRANSPORTATION ON WATER

Compare progress in water transportation with progress in land transportation (Fig. 348, p. 635) and with progress in air transportation (Fig. 6, p. 17) from the boiler enters the steam chest. When the sliding valve is in the position shown in Fig. 350, *a*, the steam from the steam chest passes into the cylinder, forcing the piston toward the left, and the used, or spent, steam on the left side of the piston is forced out through the exhaust; but by the time the piston has reached the end of the stroke, the slide valve has moved over to the right side of the steam chest (Fig. 350, *b*) so that steam from the steam chest may now enter the left side of the cylinder. The steam pushes the piston to the right, forcing the spent steam in the right end of the cylinder out through the exhaust.

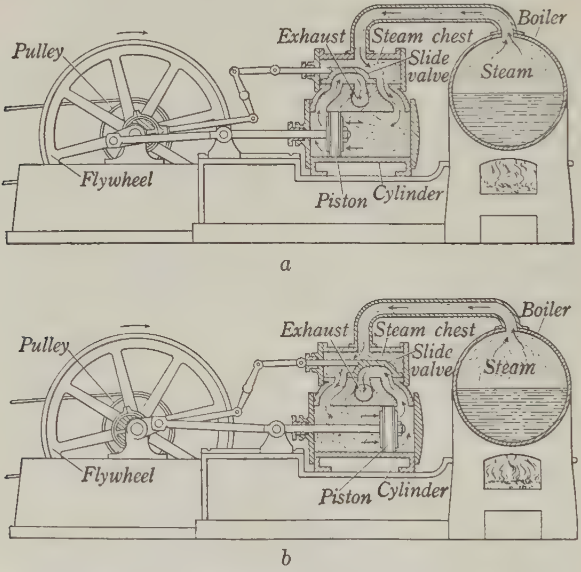

FIG. 350. DIAGRAMS OF THE WORKING PARTS OF A STEAM ENGINE

A belt over the pulley turns the machinery which the engine is to run. After reading the explanation, can you explain these diagrams?

*The piston is attached to the flywheel, which it turns as it moves back and forth. The flywheel is heavy and therefore has great inertia (see page 107), and this keeps the engine moving steadily and smoothly, even though the steam pressure against the cylinder should vary slightly.

> *Special Reports.* Describe the construction and operation of the safety valve; of the governor; of the steam turbine.

The traveling steam engine, or locomotive, is of great importance and value in transportation because it is used to pull and push thousands of trains loaded with all kinds of materials to serve human needs. The stationary steam engine is of great importance in industry because it is used to run sawmills, to run dynamos for generating power, to run machinery in factories, and for many similar purposes. The stationary steam engine is also used in steamships. It is stationary within the ship. It is of great importance, because it drives the ship in which it rides over the waterways of the world.

> *Special Reports.* How many different uses of the steam engine can you discover in one week in your town or neighborhood? How many of these have to do with transportation?

394. Modern water transportation and steel ships. Not long ago all ocean vessels were made of wood (Fig. 351). Compared with our greatest modern liners and freighters, these vessels were small. When men learned to build ships of steel they were able to build them of much greater size. But how is it possible for boats made of steel to float? Some of our greatest battleships wear on their sides steel armor more than a foot thick. Let us first find out why an object floats in water.

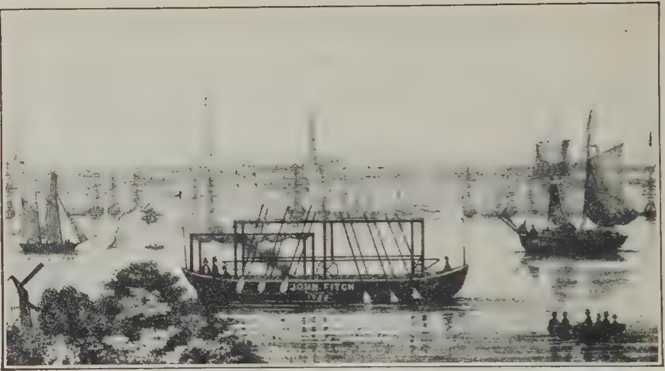

FIG. 351. THE FIRST STEAMBOATS

JOHN FITCH (1743–1798) successfully operated a passenger steamboat on the Delaware River in 1786. He even invented the engine which operated the sets of upright paddles which you see in the picture. Seventeen years before Fulton's *Clermont* made its historic trip up the Hudson, Fitch's third boat had run more than a thousand miles in regular trips up and down the Delaware. In 1796 Fitch built the first boat to be driven by a screw propeller. The United States has only lately recognized Fitch's genius, by setting aside $15,000 for a monument to him.

JAMES RUMSEY (1743–1792), also an American, was working upon a steamship at the same time as Fitch. He was given the sole rights to operate steamboats in Virginia, Maryland, and New York, just as Fitch was granted similar rights covering New Jersey, Pennsylvania, and Delaware.

WILLIAM SYMINGTON (1763–1831) constructed his steamboat, the *Charlotte Dundas*, in 1801–1802 in Scotland.

ROBERT FULTON (1765–1815) made his early experiments in France and returned to America to build his *Clermont* in 1807. Fulton never claimed to have invented the first steamboat, but only to have perfected the work which other men had begun. Fitch and the earlier inventors failed to make their boats succeed financially, but Fulton's boats were so successful that he built one after another. Before he died at the age of fifty, he had built seventeen steamboats, among them the first steam warship.

What scientific attitudes are illustrated by Fulton's work?

Experiment 87. Does an object which sinks in water lose some of its weight or all of it? Attach an iron or lead weight or a glass stopper by a string to a spring balance. Immerse the weight in water as in Fig. 352. Does the object weigh more in water than it does in air or less? Make a complete sentence answering the question at the beginning of this experiment.

Experiment 88. Does an object which floats in water lose some of its weight or all of it? Attach a wooden block in place of the iron weight used in the preceding experiment. Note how much it weighs before you put the wood on the water. How much does it weigh when you float it? Make a complete sentence answering the question at the beginning of this experiment.

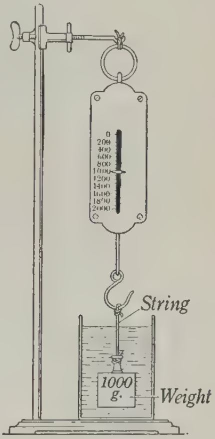

FIG. 352. WEIGHING UNDER WATER

This diagram correctly shows how to perform Experiment 82, but an error has purposely been made in drawing the spring balance. Can you perform the experiment and find the error?

*When a body is put into water, it displaces, or pushes aside, some of the water. More than two thousand years ago Archimedes,[1] a famous ancient Greek scientist, discovered that when a body is put into water it loses a weight equal to the weight of the water which it displaces. If the body displaces water enough to weigh as much as it does, it floats; if it does not displace as much water as that, it sinks. It is easy to understand why wood floats, because wood is less dense (see page 110) than water and has to sink only a little way in the water before it displaces the amount of water which weighs as much as it does. Fig. 353 illustrates these facts.

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[1] *Archimedes* (ar ki me′deez): a Greek scientist in Sicily.

*It is not so easy, however, to understand why ships made of iron (which is denser than water) can float, because a lump of iron cannot displace enough water to weigh as much as it does. The following experiment will help you to understand why iron ships can float.

FIG. 353. OBJECTS WEIGH LESS IN WATER THAN IN AIR

Experiment 89. Does a can displace more water than a lump of iron which has the same weight as the can or does it displace less? Weigh an empty tomato can or other similar can. Select a pail or other vessel which is only a little larger than the can and fill it so full of water that some spills over. Place the can on the water. Does it float? The can is like an empty iron ship, because the can is made of iron. Does it displace any water? Now put a cargo of nails or stones in the can (ship) until it barely floats. Does the ship with its cargo displace more water than it did before or does it displace less? Weigh the cargo. Can an iron ship carry a cargo which weighs more than the ship itself? Remove the can and its cargo from the water, but leave the water in the pail. Remove the cargo and pound the can into a small lump. Have you changed the weight of the can? (If you are not sure, weigh it.) Have you changed the volume of the can (that is, does it take up more or less space than before)? Put the lump of metal and all the cargo back into the pail of water. Do the metal and the cargo displace as much water as they did when the can contained the cargo? Answer with a complete sentence the question at the beginning of this experiment.

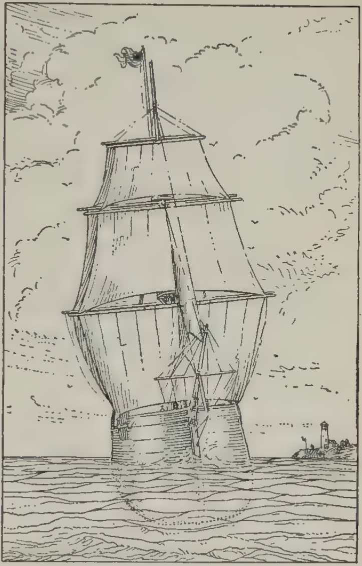


FIG. 354. A SHIP FLOATS BECAUSE IT DISPLACES WATER

This ship and everything on it together weigh two thousand tons. Therefore it sinks down in the water until it displaces two thousand tons of water. The volume of displaced water is the same size and shape as the part of the ship under water. Notice how much greater the total volume of the ship is than the volume of displaced water. Can you explain how it is possible for a piece of iron or lead to float in mercury? (Try this)

*When the iron is in the form of a lump, it cannot displace water enough to weigh as much as it does; when it is in the form of a ship, the same weight of iron has its volume increased many times. When the ship sinks down in the water, it displaces just as much water as if the part below the water were solid iron. But most of the ship's volume is made up of air, which is much less dense than the water; consequently the vessel sinks just far enough to displace enough water to equal the weight of the ship and all its cargo.

In Fig. 353 how is it possible for the boy to float? How is it easy for the boys to keep their noses above water when they swim? What would happen if all the boys got on the raft at once? Explain. How does the tire help the boy to float? Is it easier or harder for the boys to lift the stones when the stones are under water than when they are in the air? Explain.

How can the submarine (Fig. 65, p. 111) float either upon the surface of the ocean or beneath the surface?

395. †Transportation requires a knowledge of stability. If you have ever ridden in a canoe you know that the canoe is almost certain to tip over if you stand up in it, but if you sit in the bottom the canoe is not hard to keep upright. It is even less liable to tip over if you lie down in it. We know that the canoe is less liable to turn over if its passengers and cargo are as low as possible. In the same way automobile-makers put the heavier parts of the automobile as low as possible to make the automobile as stable (that is, as hard to tip over) as possible. With the weight as low as possible the automobile is less liable to turn over when it turns corners quickly or when it "skids." The cargo of a ship helps to keep the boat stable, because its weight is stored in the boat mostly below the water line. If the cargo were piled on the deck or were hung upon the masts, the boat would be almost certain to overturn when the wind blew or when the boat rolled on the waves. Ballast is often carried in the bottom of ships to make them stable when they are traveling across the ocean without cargoes.

†A body can be made more stable not only by putting the weight as low as possible but also by making the base of the body larger. Thus we have chairs with four legs — one at each corner, instead of only one under the middle of the chair. We choose lamps with big bases rather than those with little bases. For the same reason rafts are less liable to tip over than boats.

Can you give two reasons why it is easier to stand upon two feet than upon one? why a book lying on its side is more stable than when it is standing on its edge? Give other examples of stable bodies and explain why they are stable.

396. *Automobiles. The gasoline or gas engine drives the automobile and the airplane by transforming chemical energy into mechanical energy. In the gas engine the energy of exploding gasoline vapor, instead of expanding steam, moves the piston. Gasoline vapor will not explode in a vacuum: it must have oxygen for combustion just as any other fuel. The liquid gasoline is rapidly changed to a vapor and mixed in the carburetor (Fig. 355) with enough air to give the amount of oxygen necessary to make the best explosion. The explosive mixture of gasoline vapor and air goes from the carburetor into the engine.

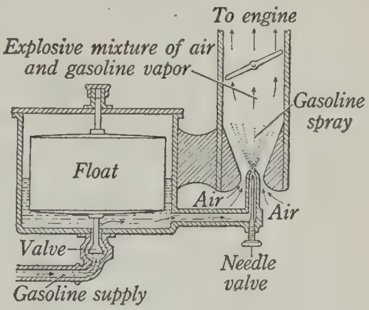
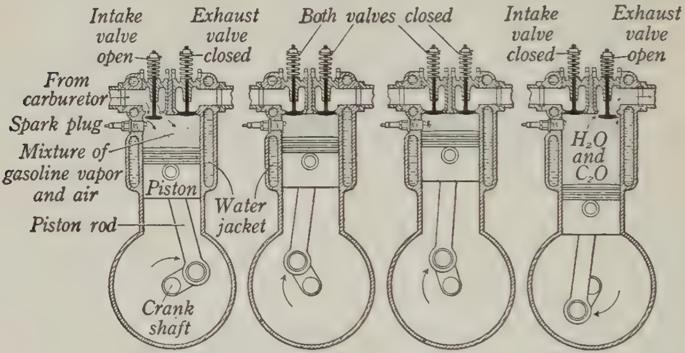


FIG. 355. DIAGRAM OF A CARBURETOR

Explain from the figure how the carburetor operates

Fig. 356 will help you to understand the four stages, or strokes, in the action of a gas engine.

*1. *The intake stroke (downward).* When the engine is started, the piston moves downward, causing a partial vacuum in the cylinder. At the same instant the intake valve opens. The air pressure outside forces air through the carburetor, carrying the explosive mixture of gasoline vapor and air from the carburetor into the cylinder.



1. Intake stroke 2. Compression stroke 3. Power stroke 4. Exhaust stroke

FIG. 356. THE FOUR PISTON STROKES OF A GAS ENGINE

The spark plug ignites the explosive mixture slightly before the piston reaches the top of the compression stroke. Why is the crank case kept partly full of oil?

*2. *The compression stroke (upward).* As soon as the piston starts up in the compression stroke, the intake valve closes. The crank shaft is attached to the heavy flywheel, the inertia (see page 107) of which keeps the flywheel turning and thus forces the piston upward, compressing the mixture of air and gasoline vapor.

*3. *The power stroke (downward).* Just before the piston reaches the top of the compression stroke an electric spark jumps between the points of the spark plug. This spark explodes the explosive mixture of air and gasoline. The energy of this explosion pushes the piston downward with great force.

*4. *The exhaust stroke* (*upward*). The inertia of the flywheel causes the wheel to keep turning, and pushes the piston upward again. But just as the piston starts upward the exhaust valve opens so that the piston can push the water vapor, carbon dioxide, and other products of the combustion of the gasoline vapor out through the exhaust pipe. The inertia of the flywheel again carries the piston downward, the intake valve opens, and the four strokes in the cycle of the gasoline engine are repeated.

*In each cylinder there is only one explosion for every two complete revolutions of the flywheel. In a four-cylinder automobile engine the pistons are so adjusted that they take turns in giving their power stroke. Thus while the first cylinder is on the intake stroke the second is on the compression stroke, the third is on the power stroke, and the fourth is on the exhaust stroke. By this arrangement one of the cylinders is delivering a power stroke as often as the flywheel makes a half revolution. The six-cylinder engine delivers a power stroke every time the flywheel makes one third of a revolution.

How many power strokes does an eight-cylinder engine deliver during each complete revolution of the fly wheel?

The gasoline engine is of great importance and value in transportation because it is used to drive automobiles (Fig. 357), airships, and boats. It is also widely used in industry to run small power plants, to run pumps, and for many similar purposes.

Special Report. How many different uses of the gasoline engine can you discover in one week in your town or neighborhood? How many of these have to do with transportation?

397. †Each automobile carries its own power house. The power house consists of a storage battery and a small dynamo, which is run by the engine. When the engine is running, it generates enough current by running the dynamo (see page 554) to light the lamps, to furnish the current for the spark plugs, and to charge the storage battery (see page 547); when the engine is not running, the storage battery furnishes enough current to start the engine and to operate the lights and other electrical circuits.

†Automobile storage cells require careful treatment. Enough distilled water (see page 59) should be added from time to time so that the solution is never below the top of the plates. The solution should also be frequently tested with a battery tester to be sure that the cell is properly charged. A fully charged cell reads from 1270 to 1300 on the battery tester. This means that the specific gravity (see page 111) is from 1.27 to 1.30. The cell needs charging again when its reading with the tester is below 1150. If the cells test differently or if anything seems wrong with them, they need the attention of the expert at the battery station.

Why is distilled water used in storage cells?

Special Reports. Describe the construction and operation of the cooling system of an automobile; of the clutch; of the transmission; of the differential; of the gears.

398. †Electric locomotives and cars. The electric motor drives the street car by transforming electrical energy into

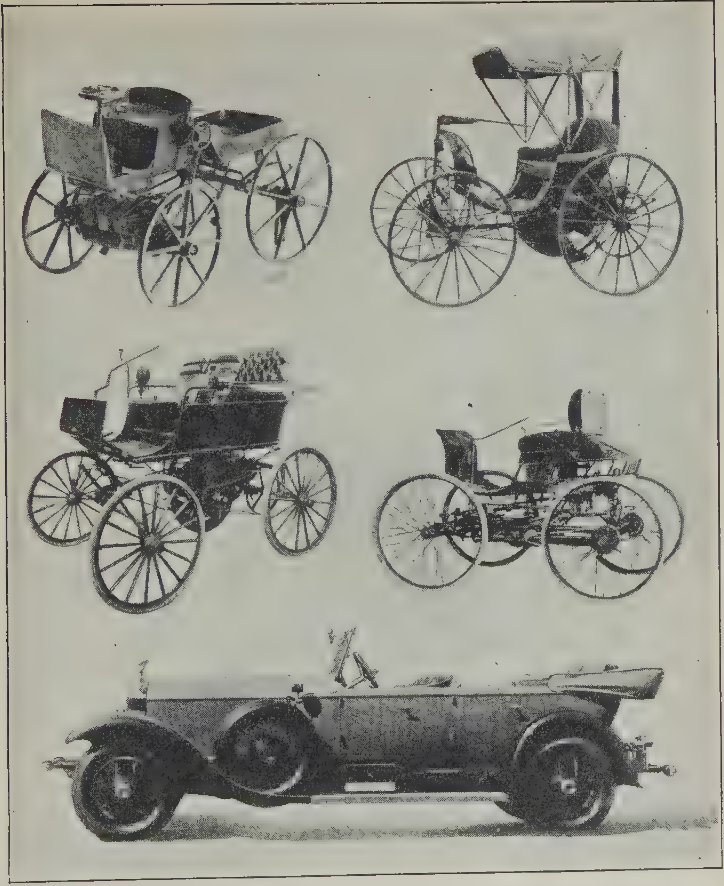


Fig. 357. The Earliest Types of Automobiles and a Modern Automobile

Top, the Selden model, from which the first patents were secured, and the first Haynes automobile; *middle*, the Duryea, recorded as the first successful automobile, and the first Packard automobile; *bottom*, a Rolls-Royce automobile mechanical energy. In Chapter XXX the dynamo was discussed. An electric motor is very much like a dynamo. In fact, if you were to buy a small D.C. (direct current) motor, the same machine could be used either as a dynamo or as a motor. The chief difference between a dynamo and an electric motor is this. In a dynamo the rotation of the armature in the magnetic field induces a current. In a

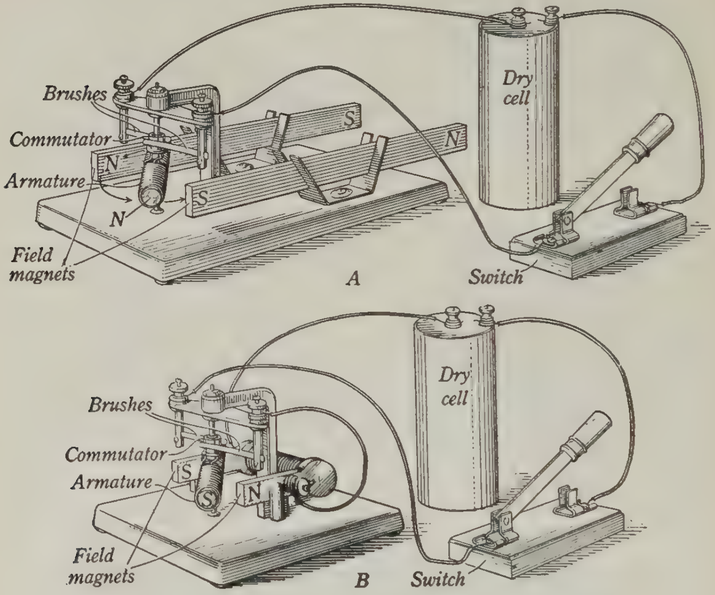


FIG. 358. DIAGRAMS OF A SIMPLE D.C. ELECTRIC MOTOR

In *A*, bar magnets are used to furnish the magnetic poles of the field; in *B*, an electromagnet is used for the field. The poles of the field in *A* and *B* are reversed; yet the armature rotates in the same direction in each diagram. Explain. In *B*, the armature and field are connected in series. Can you trace the current from the plus pole of the dry cell through the motor and back to the minus pole of the cell when the switch is closed?

motor (Fig. 358, *A* and *B*) a current is sent through the armature; this current makes electromagnets of the coils of the armature; the attraction and repulsion between the magnetic poles of these coils and the magnetic poles of the field push and pull the armature around, causing it to rotate. When the armature of the street-car motor

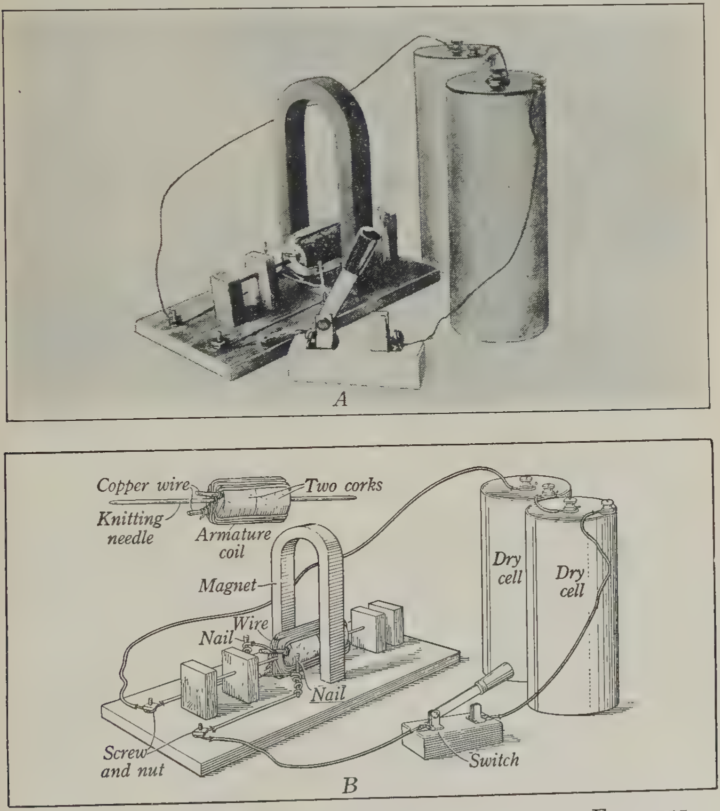


FIG. 359. *A*, A PHOTOGRAPH OF A BOY'S HOMEMADE ELECTRIC MOTOR; *B*, A DIAGRAM OF THE SAME MOTOR

rotates, cogs on the armature shaft turn other cogs on the axle of the car wheels.

> *Project.* To make an electric motor. Fig. 359, *A* and *B*, shows an electric motor made by a boy in the seventh grade. You can easily make one like it.

†The electric motor is of great importance and value in transportation, not only because it is used to drive electric cars and electric locomotives but also because recently it has come to be used to turn the propellers of ships. The electric motor, moreover, has wide uses in manufacturing plants and in and about the home (Fig. 302, p. 564).

> *Special Report.* How many different uses of the electric motor can you discover in one week in your town or neighborhood? How many have to do with transportation?

399. Airplanes and dirigibles. Most boys and girls have at some time flown a kite or perhaps made one. They know that the string has to be attached to the kite in such a way that the kite slants forward against the wind when it is flying. They know also that a kite will not fly when there is no wind. They know too that if the wind is not very strong near the ground, they can start the kite by running with it, because by running they increase the wind which is blowing against the kite, thus forcing it up to a height where the wind is stronger.

It would be very easy to fly a kite on a calm day by pulling it after a moving automobile. Pulling the kite rapidly through the still air would be the same as if the kite were held still while a strong wind blew against it.

*The airplane rises in the air for the same reason that a kite towed by an automobile would rise. The gasoline en-

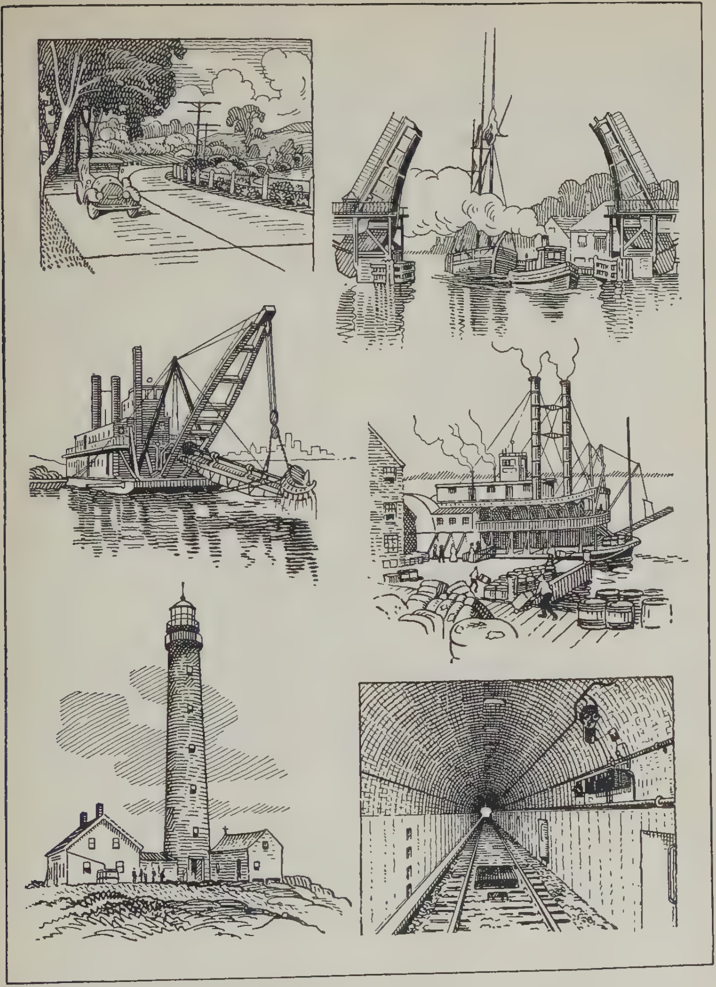


Fig. 360. Human Work and Welfare in Transportation

The gas engine and modern road construction have developed together in aiding transportation. In what ways do the drawbridge, the dredge, the levee, the lighthouse, and tunnels under rivers, under cities, and through mountains also aid transportation?

gine turns the propeller, the blades of which are so shaped that the propeller acts like a screw (Fig. 86, *b*, p. 140); it bores through the air, pulling the plane after it. At first the airplane runs along the ground while it increases its speed. The wings are tilted slightly forward like a kite, so that the wind pushes against the under side. When the propeller makes a strong enough wind against the wings by pulling the plane after it through the air, the force of the air pushes the plane up off the ground and it begins to fly. The pilot steers up or down or to the right or the left by means of rudders on the tail of the plane.

> A heavier-than-air machine must begin to descend at once if the engine stalls. Why?

Airplanes are heavier than air, but dirigibles (Fig. 6, p. 17) are like balloons in being lighter than air. Balloons and dirigibles float in the air for the same reason that boats float in water (see page 641). They are filled with hydrogen or helium, which are gases so much less dense (see page 110) than air that the whole balloon or dirigible, gas and all, weighs less than the air it displaces. Therefore it is forced upward, just as a chip of dry wood placed under the surface of water is forced upward.

Dirigibles are driven through the air by gasoline engines which turn propellers similar to airplane propellers. Dirigibles are steered by rudders at the rear end of the body.

> Can you name several ways in which the airplanes in Fig. 6, p. 17, are like a bird, and several in which they are different? What is the advantage in having the dirigible (Fig. 9, p. 25) shaped something like a fish? List structures, machines, or practices (Fig. 360) found in your community which improve transportation.

Special Reports. Discuss the uses of airplanes and dirigibles in the World War; the training of an aviator; the parachute; the Montgolfier brothers' balloon (Fig. 6, p. 17); the Wright brothers' airplane.

TESTS AND GUIDES FOR STUDY AND REVIEW

Test your knowledge by examining, and where necessary correcting or completing, the following:

1. The steam engine uses the energy of expanding ____.
2. The flywheel of a steam engine or a gasoline engine keeps the motion steady because of its **inertia friction force centrifugal force osmosis** ____.
3. Two men who were important in the early history of the steam engine were **Watt Edison Marconi Stephenson Torricelli Pasteur Jenner Harvey Fulton Galileo.**
4. When a two-pound cork is forced below the surface of water, it displaces **considerably less than two pounds of water slightly less than two pounds exactly two pounds considerably more than two pounds slightly more than two pounds.**
5. A life preserver enables the one who wears it to displace considerably more water without adding greatly to his total weight.
6. In a gas engine the mixture of gasoline vapor and air is first expanded before it is exploded.
7. Air is added to gasoline vapor in the gas engine in order to provide the nitrogen necessary to produce the combustion of the gasoline.
8. In the gas engine the explosion occurs just when the piston reaches the top of the compression stroke.
9. The propeller of an airplane pushes the airplane through the air.

BOOKS YOU WILL LIKE TO READ

The books included in this list have been selected in the main as a result of experience with the reading done by high-school pupils in science. A few of the books are added because of their known appeal to a small number of pupils especially interested in science, and for the teachers of science. This list has been selected with the following purposes in mind: (1) a list short enough and good enough so that any high-school library may reasonably be expected to have most of the books; (2) books practically all of which are known to appeal to a majority of high-school pupils who are interested in science; (3) books in which the vocabulary and style are nearly enough within the pupils' knowledge and interest to make them intelligible and engaging; (4) books which appeal to a wide variety of tastes in scientific subject matter; (5) books which provide the added interests and information and values which it is known that pupils derive from worth-while collateral reading in science. There are many other good books, and the pupil or library that gets acquainted with those on this list will be led thereby to learn of other books within the fields of chief interests.

BOND, A. RUSSELL. On the Battle Front of Engineering. Scientific American Publishing Co., New York.

Two boys have many exciting adventures while learning about some of the greatest feats of the engineers.

BOND, A. RUSSELL. Pick, Shovel and Pluck. Scientific American Publishing Co., New York.

Exciting stories and adventures having to do with the great works of the engineers, chiefly on, over, and under rivers.

BOND, A. RUSSELL. With the Men Who Do Things. Scientific American Publishing Co., New York.

Exciting stories and adventures of two boys who wanted to learn about some of the great works which the engineers plan.

CHAPMAN, WILLIAM G. Green Timber Trails. The Century Co., New York.

Stories of animals of the big woods.

DA C. ANDRADE, E. N. Engines. Harcourt, Brace and Company, New York.

For those interested in knowing how and why things run as they do.

de Kruif, Paul. Hunger Fighters. Harcourt, Brace and Company, New York.

Discussion of food and health problems; recent research.

de Kruif, Paul. Microbe Hunters. Harcourt, Brace and Company, New York.

A well-written discussion of human relations to bacteria.

Downing, Elliot R. The Third and Fourth Generation. The University of Chicago Press, Chicago.

Discusses the principles and methods by which characteristics are transmitted from one generation to another.

Fabre, Jean Henri. Insect Adventures. Dodd, Mead & Company, New York.

Uncle Paul tells the children many delightful stories of spiders, bees, wasps, and other insects.

Fabre, Jean Henri. The Wonder Book of Chemistry. The Century Co., New York.

A family of French children hear many interesting stories about chemistry from their scientist uncle, Uncle Paul.

Gibson, Charles R. Chemistry and its Mysteries. Seeley, Service & Co., Limited, London.

Interesting stories of chemistry which you will enjoy reading about and knowing about.

Gibson, Charles R. Romance of Scientific Discovery. Seeley, Service & Co., Limited, London.

Interesting scientific stories about all sorts of things from dinosaurs to planets.

Hawksworth, Hallam. The Strange Adventures of a Pebble. Charles Scribner's Sons, New York.

Strange and interesting things which scientists have learned from studying such things as rocks, mountains, and volcanoes.

Hogan, John V. L. The Outline of Radio. Little, Brown & Company, Boston.

A radio discussion which contains help of some kind for everyone who works with radio.

Jewett, Frances Gulick. The Next Generation. Ginn and Company, Boston.

An interesting book which tells how plants, animals, and human beings may be improved from generation to generation.

Lewis, Isabel M. Splendors of the Sky. Duffield & Company, New York.

Stories of planets, stars, comets, and other heavenly bodies.

McFee, Inez N. Secrets of the Stars. Thomas Y. Crowell Company, New York.

All sorts of scientific facts about the stars, the planets, and other heavenly bodies.

Mills, Enos A. Waiting in the Wilderness. Doubleday, Doran and Company, Inc., Garden City, New York.

Stories you will enjoy about wild animals of the deep forest.

Mix, Jennie I. Mighty Animals. American Book Company, New York.

About the dinosaurs and other strange creatures which lived on the earth many thousands of years ago.

Parkman, Mary R. Conquests of Invention. The Century Co., New York.

Stories of the great inventors and of how they finally succeeded in making their great inventions.

Putnam, David B. David Goes Voyaging. G. P. Putnam's Sons, New York.

An eleven-year-old boy tells his own experiences and adventures while on a scientific voyage with a great naturalist.

Rolt-Wheeler, Francis. The Boy with the U. S. Survey. Lothrop, Lee & Shepard Co., Boston.

Adventures of a boy with a party of scientists in the great Southwest, in and around the Grand Canyon, and in Alaska.

Rolt-Wheeler, Francis. The Boy with the U. S. Weather Men. Lothrop, Lee & Shepard Co., Boston.

Many exciting adventures of boys on a flooded river, in a tornado, and elsewhere.

Scoville, Samuel, Jr. Everyday Adventures. Atlantic Monthly Press, Boston.

A family of boys and girls, with their father, have all sorts of pleasant adventures while studying the wild things near their home.

Slosson, E. E. Snapshots of Science. The Century Co., New York.

Many engaging short stories about all kinds of science topics.

Talbot, Frederick A. All About Aircraft of Today. Funk & Wagnalls Company, New York.

Just what the name indicates — facts and stories about airplanes, dirigibles, and other aircraft.

GLOSSARY

SOME IMPORTANT TERMS AND THEIR MEANINGS

To the Pupil. Here is a list of important terms which have appeared in this book, with their definitions. The number following each definition is the number of the page on which the term first appears. It will help you to learn these terms if you will turn to the pages indicated and read again the paragraphs in which the terms appear.

To the Teacher. The starred words are those which appear in the Thorndike list, and the daggered words are those which appear in the Powers list, referred to in the Preface. The page references will be found to assist in accomplishing two important teaching purposes: to motivate review of essential ideas and to make the vocabulary drill more effective by connecting the definition of each term with an example of its correct use.

*__absorb__ (ab sorb′): to take in a liquid or other substance, as a blotter takes in ink (p. 89).

*__acid__ (as′id): a substance which turns blue litmus paper red (p. 116).

*__adhere__ (ad here′): to stick to, as a stamp **adheres** to an envelope (p. 29).

†**adhesion** (ad he′zhun) or **adhering** (ad here′ing): the sticking together of different kinds of substances (p. 115).

†**adulterant** (a dul′ter ant): an impurity put into foods or other materials to reduce the cost of manufacture (p. 452).

†**alloy** (al loi′): a substance formed by melting two or more metals together (p. 320).

*__alternating__ (al′ter na′ting) **current**: an electrical current which constantly reverses its direction through the circuit (p. 555).

*__altitude__ (al′ti tude): the height above sea level (p. 21).

†**amœba** (a me′ba): an exceedingly small one-celled jelly-like animal that lives in water and upon very moist earth (p. 409).

†**ampere** (am′pair): the unit of electrical current (p. 543).

†**amphibian** (am fib′i an): an animal which spends part of its life in the water and part on land, as frogs and toads (p. 409).

*__analysis__ (an al′i sis): the process of studying a substance to find what chemical elements or compounds it is made of (p. 54).

†**anatomy** (an at′o my): the study of details of structure of plants and animals (p. 465).
†**aneroid** (an′er oid): one kind of barometer in which a metal box, from which air has been removed, is used instead of a mercury column (p. 19).
***anthracite** (an′thra site): hard coal (p. 315).
anticyclone (an′ti si′klone): a high-pressure area, or "high," moving as a large slowly whirling body of air across the country (p. 219).
***antiseptic** (an′ti sep′tik): able to kill germs (p. 97).
†**antitoxin** (an′ti toks′in): a substance which is produced in a living plant or animal and which overcomes the effects of disease-producing bacteria (p. 424).
***apparatus** (ap a ra′tus): the bottles, dishes, scales, machines, and similar things which a scientist uses in experiments (p. 6).
***aquarium** (a kwa′ri um); *plural* **aquaria** (a kwa′ri a): a specially made jar or tank in which water plants and animals may be kept alive (p. 389).
†**armature** (ar′ma chur): in a simple motor or dynamo, the coils of wire which rotate between the magnetic poles of the field and in which electrical current is generated (p. 556).
†**artery** (ar′ter y): a large blood vessel which carries the blood away from the heart (p. 466).
artesian (ar te′zhan) **well**: a well bored into sloping layers of soil or rock saturated with water which is under great pressure (p. 62).
†**assimilate** (a sim′i late): to take into as part of itself, as when digested food is made into living material (p. 356).
asteroid (as′ter oid) or **planetoid** (plan′e toid): one of a group of small planet-like bodies between Mars and Jupiter, revolving around the sun (p. 256).
†**astronomer** (as tron′o mer): one who has a broad knowledge of astronomy (p. 246).
astronomical (as′tro nom′i kl): having to do with astronomy (p. 246).
***astronomy** (as tron′o my): the science of the stars and other bodies in the heavens (p. 246).
***atom** (at′om): one of the parts making up a molecule; the smallest division of matter (p. 537).
***axis** (ax′is): the line which passes through or is imagined to pass through a turning body, and upon which the body is imagined to turn (p. 258).

†**bacteria** (bak te′ri a); *singular* **bacterium** (bak te′ri um): a certain group of very small plants, some of which cause diseases (p. 74).
bacterial (bak te′ri al): having to do with bacteria (p. 417).
†**ballast** (bal′ast): sand or stones placed in a boat to make it steady (p. 24).

†**barometer** (ba rom′e ter): a device for determining the pressure of the air (p. 18).
†**barometric** (bear′o met′rik): having to do with a barometer (p. 214).
***base**: a substance which turns red litmus paper blue (p. 116).
***battery** (bat′ter y): in electricity, two or more cells connected together (p. 549).
biological (bi′o loj′i kal): having to do with biology (p. 395).
†**biology** (bi ol′o jy): the study of living things, including all plants and animals (p. 360).
biplane (bi′plane): an airplane with two planes (p. 17).
†**bituminous** (bi tu′mi nus) **coal**: soft coal (p. 315).
***blizzard** (bliz′ard): a storm in which a strong cold wind is accompanied by snow or sleet (p. 230).
***brine**: a strong solution of salt in water (p. 172).

†**caisson** (ka′son): a large air cylinder in which work is done under water (p. 32).
†**calorie** (kal′o ry): a unit of heat; the quantity of heat energy which must be put into one kilogram of water to raise its temperature 1° C. (p. 154).
†**calyx** (ka′liks): all the sepals of a flower taken together (p. 359).
†**capillarity** (kap′i lar′i ty): the rising of liquids into very small tubes or cracks (p. 354).
†**capillary** (kap′i la ry): fine, hairlike; the very small tubes through which the blood flows after leaving the arteries and before entering the veins are called capillaries (p. 466).
†**carbohydrate** (kar′bo hi′drate): food, such as sugars and starches, consisting of the element carbon and the elements in water, hydrogen and oxygen (p. 350).
***caterpillar** (kat′er pil′ler): the wormlike young of moths and butterflies (p. 393).
†**centigrade** (sen′ti grade): on the scale of one hundred (p. 160).
centrifugal (sen trif′u gl) **force**: the tendency for all parts of a whirling body to move outward from the center (p. 109).
†**cesspool** (ses′pool): a covered pit in the ground into which the sewage from a house is drained (p. 100).
***chemical** (kem′i kl): having to do with chemistry (p. 12).
†**chemist** (kem′ist): a scientist who knows and uses chemistry (p. 12).
***chemistry** (kem′ist ry): the study of substances for the purpose of finding what they are made of and how they act (p. 12).
†**chlorophyll** (klo′ro fil): the green material in plants (p. 123).
***circulate** (sur′ku late): to move by a curving path back to the starting point (p. 47).
***circulation** (sur′ku la′shun): the process by which a gas or a liquid flows to all parts of a body (p. 47).

cirrus (sir′us) **clouds:** very high, white, feather-like clouds (p. 227).

*__climate__ (kli′mat): the average of the weather conditions over a long period of time (p. 232).

cloudburst (kloud′burst): an extremely heavy and violent rainfall (p. 229).

†**coagulate** (ko ag′u late): to become like a jelly or half-solid substance (p. 468).

*__cocoon__ (ko koon′): the case in which certain insects, as the silkworm, live while developing from the larva, or worm, into the full-grown stage (p. 180).

†**cohesion** (ko he′zhun) or **cohering** (co hear′ing): the sticking together of the same kind of substance or molecules (p. 115).

†**coke:** the solid which remains after some of the gases have been removed from soft coal (p. 100).

†**combustible** (kum bus′ti bl): able to burn (p. 191).

†**combustion** (kom bus′chun): rapid oxidation producing noticeable heat and light (p. 151).

*__comet__ (kom′et): a heavenly body having a luminous head and a less bright tail (p. 282).

†**commutator** (kom′mu ta tor): a device in a dynamo or motor to keep the electrical current always flowing in the same direction through the external circuit (p. 557).

*__compound__ (kom′pound): a substance formed when two or more substances combine to form another substance which is different from any of the original substances of which it was made (p. 51).

*__compress__ (kom pres′): to squeeze together or to press into a smaller space (p. 30).

†**compression** (kom presh′un): the state of being squeezed together (p. 30).

†**concave** (kon′kave): curving inward like the inside of a ball; the opposite of convex (p. 620).

†**condensation** (kon′den sa′shun): the process of changing from a vapor or a gas to a liquid (p. 222).

*__condense__ (kon dens′): to change from a vapor or a gas to a liquid (p. 59).

†**conduction** (kon duk′shun): the transfer of heat or electricity through a substance, as a metal (p. 167).

conglomerate (kon glom′er ate): a sedimentary rock in which pebbles of various sizes are cemented together (p. 316).

†**constellation** (kon′stel a′shun): a group of stars, as the Big Dipper (p. 247).

†**contaminate** (kon tam′i nate): to make dangerously unclean; to pollute (p. 75).

†**convection** (kon vek′shun): the method by which heat travels in air or water by means of currents (p. 166).

†**convex** (kon′veks): curving outward from a center, like the outside of a ball; the opposite of concave (p. 620).
†**corolla** (ko rol′a): all the petals of a flower taken together (p. 359).
†**corpuscle** (kor′pus el): a very small body in the blood (p. 470).
crater (kra′ter): the chimney-like opening in a volcano (p. 265).
***cultivation** (kul′ti va′shun): the tilling of the soil and the culture of plants (p. 513).
cumulus (ku′mu lus) **clouds**: thick, rolling, mountain-like clouds (p. 226).
†**cyclone** (si′klone): a low-pressure area, or "low," which moves across the country as a large slowly whirling body of air (p. 217).
†**cytoplasm** (si′to plazm): the watery part of a living cell (p. 355).

***data** (day′ta): facts and observations concerning any phenomenon or happening (p. 199).
†**deciduous** (de sid′u us): shedding all its leaves at regular times (p. 481).
†**decompose** (de kom poze′): to break down a substance into simpler substances by means of heat or decay (p. 315).
†**decomposition** (de kom′po zish′un): the process of breaking down a substance by means of heat or decay into simpler compounds or elements (p. 315).
†**density** (den′si ty): the number of pounds a cubic foot of a substance weighs, or the number of grams a cubic centimeter of a substance weighs (p. 110).
***dependency** (de pen′den sy): need of support; not being able to live or act entirely alone (p. 379).
dew point: the temperature at which water vapor in the air first begins to be condensed as dew (p. 222).
†**diaphragm** (di′a fram): a thin vibrating disk or membrane (p. 585).
diastrophism (di as′tro fism): the warping and twisting of the surface of the earth as the materials of the earth are shifted under the pull of gravity (p. 298).
***diffuse** (dif fuze′): to scatter light by reflection from a rough surface (p. 598).
†**diffusion** (dif few′zhun): the reflecting of light in all directions from a rough surface (p. 598); the slow mixing of gases by the movements of the molecules of the gases (p. 53).
***digest** (di jest′): to make foods into liquids that can be used by the body (p. 356).
†**digestive** (di jest′iv): having to do with digestion (p. 443).
dinosaur (di′no saur): a reptile, often of enormous size, which lived ages ago and has long since disappeared (p. 303).
†**dirigible** (dir′i ji bl): a balloon which is propelled by a gas engine and is steered with rudders (p. 17).

*__disinfect__ (dis in fekt′): to purify by killing the germs of disease (p. 99).

†**disinfectant** (dis′in fek′tant): a substance used to kill the germs of disease (p. 99).

*__distil__ (dis til′): to evaporate a liquid and then to condense the vapor again into a liquid by cooling it (p. 59).

doldrums (dol′drums): a wide area of ascending heated air near the equator (p. 215).

dormancy (dor′man sy): a condition of prolonged quiet and lack of action; state of being dormant (p. 361).

†**dormant** (dor′mant): being in a prolonged period of rest without action (p. 239).

*__drainage__ (drain′aj): the flowing of water from higher to lower levels; also the liquids which drain (p. 75).

†**dynamo** (di′na mo): a machine used to transform mechanical energy into electrical energy (p. 555).

*__eclipse__ (e klips′): the shutting off of the light from the sun by the passage of the moon between the sun and earth, or the hiding of the moon when it passes into the shadow of the earth (p. 269).

*__efficiency__ (ef fish′en sy): the percentage found by dividing the useful work obtained from a machine by the total work put into it (p. 143).

*__electrical__ (e lek′tri kl): having to do with electricity in its various forms and uses (p. 122).

electrician (e lec trish′un): one who works with electrical appliances, materials, or currents (p. 566).

*__electricity__ (e lek tris′i ty): the form of energy appearing in electric currents and in lightning (p. 119).

†**electrify** (e lek′tri fi): to charge with electricity or electrical energy (p. 535).

†**electrolysis** (e lek trol′i sis): the process of breaking a chemical compound into its parts by sending a direct electrical current through it (p. 558).

†**electromagnet** (e lek′tro mag′net): a soft iron core with a coil of wire wound round it. When a current of electricity is sent through the wire, the soft iron becomes a temporary magnet (p. 553).

†**electromotive** (e lek′tro mo′tiv) **force** or **E. M. F.**: electrical pressure or voltage (p. 543).

†**electron** (e lek′tron): according to the electron theory of electricity, one of the negatively charged particles circling around the nucleus of the atom (p. 537).

†**electroplate** (e lek′tro plate′): to plate or coat with metal by means of a direct electric current (p. 559).

electrotype (e lek′tro type): to produce a metal copy of the surface of a page of type for printing by means of a direct electric current (p. 560).

*__element__ (el′e ment): a substance which cannot be broken up into a simpler substance. Compounds are made up of elements (p. 51).
*__energy__ (en′er jy): the capacity to do work (p. 119).
†**entomology** (en′to mol′o jy): the study of insects (p. 402).
†**environment** (en vi′ron ment): all the surroundings and conditions among which a plant or animal lives (p. 6).
*__equator__ (e kway′tor): the imaginary line round the earth halfway between the north and south poles, where the vertical rays of the sun strike March 21 and September 22 (p. 214).
equatorial (e′kway to′ri al): having to do with the equator (p. 214).
equatorial calms or **doldrums**: a wide area of ascending heated air near the equator (p. 215).
equinox (e′kwi noks): March 21 or September 22, the date on which the direct rays of the sun reach either the tropic of Cancer or the tropic of Capricorn (p. 334).
erode (e rode′): to wear away (p. 294).
†**erosion** (e ro′zhun): the process by which portions of the rock and soil at and near the earth's surface are scraped or scoured off and carried away by ground water, running water, winds, glaciers, and ocean currents (p. 291).
*__eruption__ (e rup′shun): a pouring out of matter, as from a volcano (p. 259); a breaking out on the skin (p. 429).
†**esophagus** (e sof′a gus): the tube which carries the food from the mouth to the stomach (p. 469).
*__evaporate__ (e vap′or ate): to change a liquid or a solid into a vapor by heating it (p. 44).
†**evaporation** (e vap′o ra′shun): making a solid or a liquid into a vapor by heating it (p. 44).
*__evergreen__ (ev′er green): a plant that always has green leaves (p. 480).
*__exhale__ (ex hale′): to breathe out (p. 41).
*__expand__ (ex pand′): to swell out; to increase in volume (p. 43).
*__expansion__ (ex pan′shun): the act of increasing in volume, as when heated (p. 43).
*__explosion__ (ex plo′shun): the rapid expansion of gases with violence resulting from very rapid oxidation (p. 43).
†**explosive** (ex plo′siv): a substance that produces an explosion (p. 43).

†**Fahrenheit** (fah′ren hite): a German physicist; the thermometer scale named for its inventor, in which the freezing point of water is 32° and the boiling point 212° (p. 160).
†**fermentation** (fur′men ta′shun): the production of alcohol and carbon dioxide by action of yeast or bacteria (p. 381).
*__fertility__ (fer til′i ty): ability to support the growth of plants (p. 486).
*__fertilize__ (fer′ti lize): to make fertile; to make capable of reproducing (p. 327).

†**filter** (fil′ter): a device or porous substance used to remove solid particles from a liquid; to pass through a filter (p. 83).

†**foot-pound**: the unit of mechanical work; the work done in raising a pound of anything one foot (p. 128).

***force**: a push or a pull (p. 124).

†**fossil** (fos′sil): the forms or remains of ancient plants or animals preserved in earth or rock (p. 303).

†**friction** (frik′shun): the opposition to the movement of one body against another (p. 36).

†**fulcrum** (ful′krum): the pivoting point of a lever (p. 134).

†**fungus** (fung′gus); *plural* **fungi** (fun′ji): a simple plant which has no chlorophyll (p. 380).

***fuse**: in electricity, a piece of wire which melts at a low temperature inserted into an electrical circuit for protection in case too much current passes through the circuit (p. 567).

galaxy (gal′ax y): an enormous cluster of suns in the heavens; the Milky Way (p. 252).

†**gaseous** (gas′e us): like a gas or vapor (p. 107).

***gauge** (gaje): an instrument for measuring, as for water, steam, or air pressure (p. 80).

***gear**: a wheel having teeth on the rim and serving to carry motion from one place to another, or to change the rate or direction of rotation (p. 141).

***germ** (jurm): a very small plant or animal which may produce disease (p. 75).

†**germicide** (jur′mi side): a substance which kills bacteria or animal germs (p. 424).

†**germinate** (jur′mi nate): begin to grow, as from a spore or a seed (p. 384).

***geyser** (gi′zer): a hot spring which frequently spouts boiling water and steam (p. 312).

***glacier** (gla′sher): a river of ice slowly flowing downward (p. 295).

***gland**: an organ for making a special kind of body fluid (p. 469).

***gradation** (gra da′shun): the leveling of the earth's surface by carrying the soil and rocks of the hills and mountains into the valleys and finally into the ocean basins (p. 290).

†**gravitation** (grav′i ta′shun): the attraction any body has for any other body (p. 110).

***gravity** (grav′i ty): the attraction any body has for any other body, but especially the force which pulls objects to the earth (p. 110).

grounded circuit (sur′kit): in electricity, a path for the current which is made complete by connecting it with the earth instead of entirely through metal (p. 551).

†**hæmoglobin** (hem′o glo′bin): the coloring material of the red blood corpuscles (p. 470).

†**heredity** (he red′i ty): the possession of characteristics and qualities inherited from ancestors (p. 411).

†**hibernation** (hi′ber na′shun): the habit among animals of passing long cold or dry periods in a state of inaction or dormancy (p. 362).

***high**: a region of higher barometric reading, that is, a high-pressure area or anticyclone (p. 214).

†**horse power**: the unit of power, or the rate of doing work, equal to 33,000 pounds lifted one foot in one minute (p. 143).

***host**: the plant or animal upon or in which a parasite lives (p. 415).

†**humid** (hu′mid): moist, filled with water vapor (p. 223).

†**humidity** (hu mid′i ty): water vapor in the air (p. 223).

†**humus** (hu′mus): rich soil produced from the decay of animal or vegetable matter (p. 486).

†**hydraulic** (hi draw′lik): having to do with water, its pressure and force (p. 70).

†**hydrocarbon** (hi′dro kar′bon): a chemical compound that contains carbon and hydrogen only (p. 317).

hydroplane (hi′dro plane): an airplane which rises from water and lands on water (p. 22).

†**hygiene** (hi′gene): the study of the proper care of the body (p. 478).

†**hypothesis** (hi poth′e sis); *plural* **hypotheses** (hi poth′e seez): a statement constructed to explain scientific phenomena, but not fully proved to be a true or correct explanation (p. 285).

igneous (ig′ne us): having to do with fire; rock which has been melted by volcanism, that is, by the earth's heat (p. 302).

image (im′aj): a picture produced by refraction or reflection (p. 598).

†**immune** (im mune′): free from or protected against (p. 425).

***immunity** (im mu′ni ty): the condition of being immune or free from; usually applied to freedom from disease (p. 425).

†**incandescent** (in′kan des′ent): white-hot or glowing with heat (p. 42).

induced current: an electrical current produced by moving a conductor in a magnetic field (p. 554).

†**inertia** (in er′shi a): the tendency not to change the state of rest or motion unless acted upon by an outside force (p. 107).

***infect** (in fekt′): to transfer harmful germs to wounds or to well people. This occurs when well people touch objects that have germs upon their surfaces (p. 422).

***infection** (in fek′shun): the act of infecting or the condition of being infected (p. 422).

***infectious** (in fek′shus): able to be transferred by infection (p. 422).

†**inhale** (in hale′): to breathe in (p. 41).

***inherit** (in her′it): to be born with a characteristic or quality which a parent or more distant ancestor had (p. 418).

***instincts** (in′stinkts): habits which we inherit from our parents without having to learn them (p. 477).

***insulate** (in′su late): in electricity, to separate a wire or other conductor from other conductors by a layer or layers of nonconducting material (p. 550).

†**insulation** (in′su la′shun): in electricity, the materials used to cover the conductors of electric current (p. 550).

***insulator** (in′su la tor): a nonconductor such as hard rubber or glass; any substance through which an electric current passes only slightly or not at all (p. 538).

†**intestinal** (in tes′ti nal): having to do with the intestines (p. 77).

***intestine** (in tes′tin): the tubelike lower part of the digestive system (p. 421).

†**invertebrate** (in ver′te brate): an animal having no backbone or spinal column (p. 410).

***involuntary** (in vol′un ta ry): without control, or acting without planning or without being guided (p. 459).

***irrigation** (ir ri ga′shun): watering land by artificial means for agricultural purposes (p. 64).

kindling temperature (tem′per a ture) or **kindling point**: the temperature at which a substance begins to burn (p. 186).

†**kinetic** (kin et′ic) **energy**: the energy possessed by moving bodies of matter (p. 119).

***laboratory** (lab′o ra to ry): a place where a scientist works (p. 6).

†**larva** (lar′va); *plural* larvæ (lar′vee): the wormlike young of an insect (p. 395).

***latitude** (lat′i tude): distance north or south of the equator on the earth's surface (p. 343).

***lens**: a piece of glass made so as to refract light in a certain way (p. 620).

†**lichen** (li′ken): a primitive form of plant (p. 502).

†**lodestone** (load′stone): a rock which is a natural magnet, that is, which attracts iron and steel (p. 527).

***longitude** (lon′ji tude): distance east or west on the earth's surface; measured from the prime or zero meridian which passes through Greenwich (p. 339).

***low**: a region of low barometric reading; a low-pressure area; a cyclone (p. 214).

†**lubrication** (lu′bri ka′shun): using fluids, such as oil, to lessen friction (p. 47).

***luminous** (lu′mi nus): giving off light, as the sun (p. 254).

lunar (lu′nar): having to do with the moon (p. 265).

***magnet** (mag′net): a piece of iron, steel, or other metal which attracts iron or steel (p. 51); a coil of wire through which an electric current is flowing is also a magnet (p. 553).

†**magnetic** (mag net′ic) **field**: the space round a magnet where the magnet can exert a force and do work upon iron or steel (p. 532).

†**magnetic induction** (in duk′shun): the process of magnetizing a piece of iron or steel by bringing it near a magnet (p. 533).

magnetic lines of force: the invisible lines of magnetic energy which surround a magnet and which make up the magnetic field of force (p. 532).

†**magnetize** (mag′net ize): to make into a magnet (p. 529).

†**mammal** (mam′mal): an animal which produces milk to feed its young (p. 409).

***matter** (mat′ter): anything that occupies space and has weight (p. 106).

***mechanical** (me kan′i kl): having to do with moving matter, particularly machinery (p. 122).

†**membrane** (mem′brane): a thin lining or covering (p. 352).

***meridians** (me rid′i ans) **of longitude**: imaginary lines drawn on the earth's surface running north and south from pole to pole (p. 339).

†**metallic** (me tal′ik): containing a metal, being like a metal, or being a metal (p. 319).

metamorphic (met′a mor′fik) **rock**: sedimentary or igneous rock which has been changed by high temperature, pressure, water in the rock, and sometimes movement (p. 302).

***meteor** (me′te or): a "shooting star"; a stone which in falling through the atmosphere is burned up, leaving for an instant a bright trail (p. 283).

†**meteorite** (me′te or ite): a stone which falls through our atmosphere and upon the earth (p. 256).

†**metric** (met′rik) **system**: a system of weights and measures in which each unit is ten times the next smaller unit (p. 144).

†**microscope** (mi′kro skope): an optical instrument which makes objects look larger than they are (p. 7).

†**migrate** (mi′grate): to go to a new home or to a different region (p. 239).

***migration** (mi gra′shun): the journey made when animals seek a new home (p. 239).

mirage (mi razh′): an image, as of water or vegetation, seen often over a desert. It is due to the refraction of light (p. 603).

***mirror** (mir′ror): any opaque object with a surface smooth enough to reflect the light in such a way as to show an image of objects in front of the surface (p. 598).

*__mixture__ (mix′chur): the result of mixing two or more substances together without changing the nature of the substances (p. 51).

*__molecule__ (mol′e kule): the smallest part of a substance that can exist by itself (p. 113).

monoplane (mon′o plane): an airplane having one pair of wings (p. 17).

neap tides: the tides at first and third quarters of the moon (p. 273).

nebula (neb′u la); *plural* **nebulæ** (neb′u lee): a gaseous body in space collected around a central lump or knot (p. 289).

*__nectar__ (nek′tar): the sweet liquid found in many kinds of flowers (p. 364).

*__neutral__ (noo′tral): in electricity, neither positively nor negatively charged (p. 538).

nimbus (nim′bus) **clouds**: heavy dark-gray clouds from which rain or snow may fall (p. 226).

†**nodule** (nod′ule): an enlarged joint or small knot, as on a clover root (p. 418).

nonconductor (non′kon duk′tor): an insulator; any substance through which an electric current passes with difficulty or not at all (p. 538).

nonluminous (non lu′min us): not giving off light of itself, but more or less able to reflect light, as the moon (p. 597).

norther (nor′ther): a violent wind storm coming from the north or northwest (p. 231).

†**nucleus** (new′kle us): the denser, usually central, part of a cell (p. 355) or of an atom (p. 537).

†**ohm** (ome): the unit of electrical resistance (p. 544).

†**opaque** (o pake′): not allowing light to pass through (p. 597).

*__optical__ (op′ti kl): relating to vision; having to do with seeing (p. 621).

*__orbit__ (or′bit): the path of a heavenly body round a larger body, as the orbit of the moon round the earth or of the earth round the sun (p. 250).

†**organic** (or gan′ic): having to do with organisms — plants and animals (p. 384).

†**organism** (or′gan izm): an animal or a plant; a body that has special parts for special work (p. 46).

†**osmosis** (os mo′sis): the passing of liquids or gases through membrane from the place where the liquid or gas is more concentrated to the place where it is less concentrated (p. 354).

†**ovary** (o′va ry): in a flower, the enlarged part of the pistil which holds the ovules (p. 359).

†**ovule** (o′vule): the egg-like body contained within the ovary; the fertilized ovule becomes the seed (p. 359).

†**oxidation** (ox′i da′shun): the act of uniting with oxygen, or the state of being united with it (p. 42).

†**oxide** (ox′ide): a substance chemically combined with oxygen, as carbon dioxide or water (p. 48).

†**oxidize** (ox′i dize): to combine with oxygen (p. 42).

†**parachute** (pair′a shoot): an umbrella-like device used in descending from airplanes and balloons (p. 17).

***parallels of latitude** (lat′i tude): imaginary circles running east and west around the earth parallel with the equator (p. 343).

†**parasite** (pair′a site): a living plant or animal which lives on, inside, or at the expense of another plant or animal (p. 77).

†**pasteurize** (pas′tur ize): to prevent bacterial action in a liquid, as milk, by heating it and then cooling it (p. 448).

penumbra (pe num′bra): the lighter part of a shadow which surrounds the deepest shadow and which receives some light directly from part of the source of light (p. 600).

†**percussion** (per kush′un) **instruments:** musical instruments that are played by being struck (p. 584).

†**periscope** (per′i skope): a device which uses refraction and reflection of light to enable people to see around corners (p. 603).

***perspiration** (pur′spi ra′shun): moisture given off by the body through the pores of the skin (p. 223).

***petroleum** (pe tro′le um): crude oil from an oil well (p. 315).

***phase** (faze): one of the forms or views presented by the moon or one of the planets (p. 263).

†**phenomenon** (fe nom′e non); *plural* **phenomena** (fe nom′e na): any happening is a phenomenon (p. 10).

†**photosynthesis** (fo′to sin′the sis): the process by which green plants use the energy of sunshine to make starches and sugars from carbon dioxide and water (p. 350).

†**physicist** (fiz′i sist): one who studies the science of forces and forms of energy (p. 18).

†**physiology** (fiz i ol′o jy): the study of the structures of the body and how they work (p. 478).

†**pistil** (pis′til): the central structure of a flower, which contains the ovary and ovules (p. 359).

***piston** (pis′ton): a disk made to slide back and forth in a cylinder (p. 36).

***pitch:** in music, the highness or lowness of a tone, depending upon the number of vibrations which the sounding body makes in a second (p. 582).

planetesimal (plan et es′i ml): a small piece of matter in the heavens (p. 285).

†**scientist** (si′en tist): one who makes a study of science, that is, of things found in nature (p. 6).

***sediment** (sed′i ment): solid or undissolved particles in water or other liquid (p. 84).

sedimentary (sed′i men′ta ry) **rock**: rock formed by the slow hardening and cementing together of layers of sediment which slowly collected in the bottoms of oceans and lakes (p. 299).

†**sepal** (se′pal): one of the leaves at the base of the petals of a flower (p. 359).

septic (sep′tik): producing decay through the action of certain kinds of bacteria (p. 98).

septic tank: a box or tank buried in the ground, in which sewage is made harmless by the action of bacteria (p. 98).

†**serum** (se′rum): the watery portion of the blood (p. 425).

†**sewage** (su′ij): the waste matter which flows from toilets and from streets through pipes called sewers (p. 77).

***sewer** (su′er): the pipes for conducting sewage from toilets and streets (p. 77).

short circuit (sir′kit): the passage of an electric current over a path it was not intended to take (p. 549).

†**siphon** (si′fon): a tube through which liquid is forced from a higher to a lower level by air pressure (p. 67).

***skeleton** (skel′e tun): the supporting frame of a building or of an animal body (p. 460).

***sleet**: rain with snow or ice in it or rain which freezes while falling or as it strikes the earth (p. 219).

†**solar** (so′lar): having to do with the sun (p. 250).

solstice (sol′stis): the date on which the sun's vertical rays reach the tropic of Cancer or the tropic of Capricorn (p. 336).

†**soluble** (sol′u bl): able to be dissolved (p. 291).

***solution** (so lu′shun): a liquid in which a solid or a gas has dissolved (p. 52).

***solvent** (sol′vent): a substance in which another substance dissolves (p. 58).

specific (spe sif′ik) **gravity** (grav′i ty): the weight of a given volume of any substance compared with the weight of an equal volume of water (p. 111).

†**spectroscope** (spek′tro scope): an optical instrument, having a prism through which light from an incandescent body is viewed (p. 250).

speedometer (speed om′e ter): a device for measuring how far and how fast an automobile or other vehicle travels (p. 146).

†**spherical** (sfer′i kl): like a sphere (p. 528).

***spiral** (spi′ral): shaped like a curl, or like the path one would make in going round and round a point while getting constantly farther away from the point (p. 140).

†**spore**: the reproductive body in nonflowering plants, such as molds or ferns (p. 379).

spring tides: the tides at new and full moon (p. 273).

†**stability** (sta bil′i ty): the state of being firm or steady, so as not to be easily tipped over (p. 644).

†**stamen** (sta′men): the part of a flower which contains the pollen (p. 359).

†**static** (stat′ik) **electricity**: electricity which is not flowing as a current (p. 535).

†**stratum** (stra′tum); *plural* **strata** (stra′ta): a layer; especially applied to rocks, clouds, and soil (p. 61).

stratus (strat′us) **clouds**: layers or strata of low drifting clouds, probably a fog bank above the ground (p. 226).

†**submarine** (sub′ma reen): under the ocean; a ship which can travel beneath the ocean surface (p. 112).

†**suction** (suk′shun): when a greater pressure forces something toward or into a partial vacuum the process is called suction (p. 29).

sun spot: a violent storm upon the surface of the sun (p. 258).

sun time: the exact hour of the day at any point on the earth (p. 339).

***superstition** (su′per stish′un): a belief in causes which are not natural (p. 8).

***superstitious** (su′per stish′us): believing in signs and omens (p. 8).

suture (su′choor): joint formed by bones fitted together like the teeth of two saws or like the wooden edges of a dresser drawer (p. 463).

***switch**: in electricity, a device for completing or breaking an electric circuit (p. 566).

†**synthesis** (sin′the sis): the process of building up a substance by combining chemical elements or compounds (p. 54).

***telescope** (tel′e skope): an optical instrument used to study objects, such as stars and planets, which are too far away to be seen clearly with the naked eye (pp. 7, 250).

†**tendon** (ten′don): the strong end of a muscle by which it is attached to a bone (p. 464).

***terminal** (tur′min al): in electricity, the pole or metal part of a cell or other electrical device to which the wires are connected (p. 549).

***terrestrial** (te res′tri al) **planets**: the four smaller planets (p. 260).

†**tidal** (ti′dl): having to do with the tides (p. 273).

***tissue** (tish′u): a part of a plant or animal made of cells all of the same kind (p. 419).

†**tornado** (tor na′do): a type of small, violently whirling, very destructive wind (p. 219).

torrid zone: the portion of the earth's surface between the tropics of Cancer and Capricorn, and upon which the direct rays of the sun fall during the year (p. 337).

†**toxin** (toks'in): a poisonous substance produced by disease-producing bacteria during their growth (p. 424).

***transformer** (trans form'er): in electricity, a device for increasing or decreasing the voltage or electrical pressure in a circuit (p. 564).

†**translucent** (trans lu'sent): allowing some light to pass through, but not enough to permit objects to be clearly seen through the substance (p. 597).

***transparent** (trans pair'ent): allowing sunshine to pass through so that objects can be clearly seen through the substance (p. 165).

†**transpiration** (tran'spi ra'shun): the exhaling or evaporating of water from the surface of a plant into the air (p. 349).

tree surgery (sur'jur y): the pruning, repairing, and general care of trees by experts (p. 497).

***tropical** (trop'i kl): having to do with the tropics (p. 240).

tropics (trop'iks): the region near the equator (p. 240).

†**turbine** (tur'bin): a special type of water wheel (p. 67).

umbra (um'bra): the darkest part of the shadow; the part which receives no light directly from the source (p. 600).

†**urine** (u'rin): the fluid waste material taken from the blood by the kidneys and stored in the bladder until its removal (p. 471).

†**vaccination** (vak'sin a'shun): the process of introducing a mild form of disease by use of weakened or dead germs or of the products from these germs (p. 428).

***vacuum** (vak'u um): a space from which all the air or other substances are removed (p. 18).

***valve** (valv): a device within a pipe or tube by means of which a passage is closed or opened (p. 35).

†**vaporize** (va'per ize): to change to a vapor (p. 107).

vaporous (va'por us): like a vapor (p. 107).

***vegetation** (vej'e ta'shun): plant life of any sort (p. 239).

***ventilate** (ven'ti late): to produce a free circulation of air (p. 175).

†**ventilation** (ven'ti la'shun): provision for a free circulation of air (p. 175).

†**vertebrate** (ver'te brate): an animal having a backbone or vertebral column (p. 409).

***vibrate** (vi'brate): to move to and fro, as the wings of a buzzing insect (p. 167).

†**vibration** (vi bra'shun): a movement to and fro, as a clock pendulum (p. 167).

†**vitamin** (vi'ta min): a substance essential to the diet (p. 444).

vitrify (vit′ri fy): to add a glassy surface to dishes and tiles, which closes the pores (p. 98).

vivarium (vi va′ri um); *plural* **vivaria**: a place for keeping either land or water animals alive (p. 390).

volcanism (vol′kan ism): the process producing changes in the surface of the earth due to the effects of heat within the earth (p. 297).

***volt**: the unit of electrical pressure, or voltage, or electromotive force (E. M. F.) (p. 543).

†**voltage** (volt′aj): the pressure of an electrical current; the same as electromotive force, or E. M. F. (p. 543).

***voluntary** (vol′un ta ry): as one wishes, or acting of one's own accord (p. 459).

water cycle (sy′kl): the continuous round of water through the processes of evaporation and condensation (p. 222).

***weather** (weth′er): the conditions from day to day with respect to air pressure, humidity, rainfall, clouds, sunshine, and the winds (p. 232).

weathering (weth′er ing): the process of breaking up and changing rock into soil (p. 291).

zero meridian (mer id′i an): the meridian of longitude which passes through Greenwich, England, and which is used as the starting point for the numbering of the meridians (p. 339).

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